AMERICAN WOOL HANDBOOK

A PRACTICAL TEXT AND REFERENCE BOOK FOR THE ENTIRE WOOL INDUSTRY

BY

WERNER VON BERGEN

Director of Research, Forstmann Woolen Company
Formerly Teacher of Wool Manufacture, Columbia University
Fellow of the Textile Institute

AND

HERBERT R. MAUERSBERGER

Textile Consultant, Editor, formerly
Head of Evening Textile Courses, Columbia University
President, Textile Book Publishers, Inc

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FOREWORD

WOOL has been indispensable for many centuries, because it provides us with our most important body covering. The history and utilization of wool is a fascinating tale of adventure, sacrifice and inventive genius. From a crude beginning the Wool Textile Industry has become an industrial giant, playing an influential part in the development of this country

Continued change and progress in research as well as technique have made it necessary to revise and enlarge this book The authors have adhered to the same excellent presentation as was used in the first edition It remains the most comprehensive study of the wool textile industry with special emphasis on existing American practice

The authors deserve much credit for their painstaking efforts in bringing this volume up to date Mr Werner von Bergen is one of the leading experts in wool technology and was a consultant to the Quartermaster General as a member of the textile team during the last war He is now director of research of Forstmann Woolen Company of Passaic, N J, and formerly a teacher of wool manufacture at Columbia University

Mr. Herbert R Mauersberger is a technical editor of one of the leading trade publications and was formerly in charge of the evening textile courses at Columbia University He is a textile consultant and is president of Textile Book Publishers, Inc

In its second edition, this book will provide the trade with up to date and authoritative references on all phases of wool production and manufacture

ARTHUR BESSE, *President*
NATIONAL ASSOCIATION OF WOOL MANUFACTURERS

New York, N Y.
December, 1947.

AUTHORS' PREFACE

IN the first edition, the authors expressed the hope that this book would find its place as a practical reference and textbook for the entire wool industry The fact that the first edition was exhausted within such a short time indicated that there was a long-felt need for such a handbook The authors regret that World War II delayed publication of a second edition until this time

The chief aim in the preparation of this new edition has been to bring the material up to date by careful revision and expansion of certain portions of the text This was especially important because of extensive changes in processes and equipment which have been made since 1938, particularly in streamlining mass production techniques through the increased use of machinery to produce a more continuous and efficient flow of goods

Because of the added knowledge gained by extensive research in the last few years, it became necessary to divide the physical and chemical properties of wool into two chapters Various methods of producing shrink-resistant woolens have been included Marketing of wool appears as a separate chapter and includes an expanded account of international trade and futures trading in wool and wool tops The continuous solvent degreasing and continuous wool grease recovery processes are described for the first time Twist tables are given for woolen and worsted yarns which have never before been published and descriptions of atmospheric conditions suitable for wool processing have been added to the spinning sections The chapters on worsted yarn manufacturing have been revised extensively to include the latest information on combs and spinning frames, with particular emphasis on high drafts and variable speed spinning, as well as a detailed explanation of the new American system of spinning Under weaving, coning and rewinding of warp and filling yarns are discussed in greater detail A new section on matching of colors and the use of instruments has been added The description of continuous indigo dyeing in both raw stock and pieces, and of the latest methods of mothproofing are also new material

The chapter on finishing contains detailed accounts of continuous washing and fulling machinery, and the new infra-red baking process used in carbonizing Descriptions of pressing and sponging processes in dry finishing have been expanded to include a survey of the latest

machinery and methods. The discussions of felts and carpets have been divided into separate chapters.

The increased space allotted to the testing chapter which places special emphasis on quality control is indicative of the advances made in testing methods. The chapter on wool literature is much more comprehensive, including tariff schedules and the Wool Products Labeling Act. Because of the addition of this new material, the chapter on dry cleaning, the woolen and worsted glossary, and the dyestuff appendix had to be omitted.

For valuable assistance in the preparation of this second edition, the authors are indebted to collaborators and contributors far too numerous to name individually. However, special acknowledgement is made to G. F. Brown of the National Association of Wool Manufacturers, who in Chapter 1 covered the most recent background material; E. A. Beveridge of Merrill, Lynch, Pierce, Fenner and Beane who wrote "Futures Trading in Wool and Wool Tops"; H. Millson of Calco Chemical Company who prepared the section on the matching of colors and assisted in the revision of dyeing procedures; L. Garfunkel of the Texurity Guild who again wrote the division entitled "Conditioning Before Cutting Up;" N. B. Pope of the Felt Association who prepared the text on non-woven felts; R. K. Brooks of Charles W. House and Sons who wrote the story of woven felts; T. Crowley of the American Chemical Paint Company for his assistance in revising the chapter on scouring of raw wool; and A. G. Ashcroft of the Alexander Smith and Sons Company who assisted in revising the chapter on carpets. The authors are also indebted to R. Burns of the University of Wyoming, J. F. Wilson of the University of California, W. Mueller of the Wool Division of the Department of Agriculture, J. I. Hardy of the Bureau of Animal Industry, L. Tanner of the United States Customs Laboratory, H. Ehrhardt of the Botany Worsted Mills, H. R. Anderson of the Abbot Worsted Company, L. L. Walmsley of the American Viscose Corporation, N. A. Whiffen of the Australian Embassy, and E. Ackerman of the American Wool Council for their contributions of valuable technical information.

The authors are especially indebted to the Forstmann Woolen Company, its supervisors and members of the laboratory staff who gave their valuable assistance. They are grateful for the privilege of using their original and valuable photomicrographs, charts and other illustrations, many of which were specially prepared by G. Moro and W. Wetzold.

It is a privilege to have Mr Arthur Besse, President of the National Association of Wool Manufacturers, consent once more to write the foreword The authors are grateful to him and to his staff for their continuing interest in this work

As in the first edition, the authors have been encouraged by substantial advertising from wool dealers and merchants, manufacturers of dyes, chemicals and wool machinery, as well as others who serve the American Wool Industry This splendid support and close cooperation is gratefully acknowledged

In presenting the second edition, the authors hope that the addition of information on recent developments will increase its usefulness as a valuable reference and textbook to all students, trainees, mill men, and others seeking facts about the wool industry

WERNER VON BERGEN
HERBERT R MAUERSBERGER

December, 1947
New York, N Y

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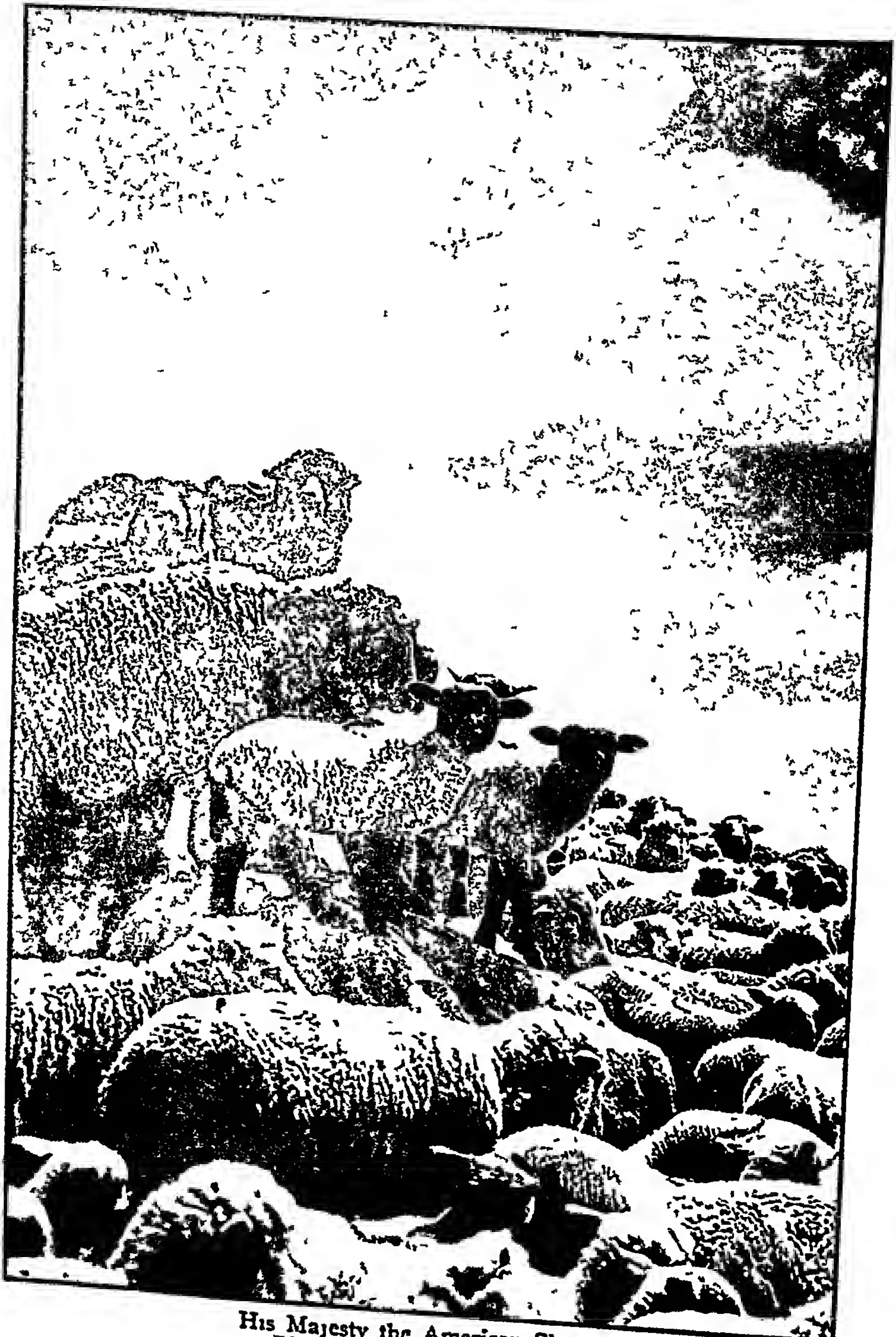


His Majesty the American Sheep
Photo by Charles J. Belden

Chapter 1

HISTORICAL AND ECONOMIC BACKGROUND

WOOL was spun and made into cloth many years before the beginning of recorded history The ancient Egyptians, Babylonians, Greeks and Hebrews did hand-spinning and hand-weaving in the home, even women of high rank made their own clothing The wool industry all over the world developed along the lines of a household craft rather than as a primitive factory system Both systems seem to have existed in ancient Rome The Romans usually wore wool clothing Their *toga denea* or *hirta* (thick or hairy toga) was worn in the wintertime and the *toga tirta* or *rosa* (thin or smooth toga) was worn in the summertime The former obviously was made of a heavily napped woolen cloth and the latter of a light material similar to worsted During the early Christian Era, the finest woolen "stuffs" were made in Bagdad, Damascus, and other cities of the Turkish Empire In the Middle Ages, the woolen industry flourished in Italian cities such as Venice and Florence, from where it spread to the Netherlands, Belgium, and later to England

Early American Beginnings

According to Arthur H Cole[1] the handicraft system was represented in the colonial period only by specialized weavers, fullers, and worsted-cloth makers The household craft was found in the earliest colonial settlements In fact, the beginning of the American wool industry is traced to 1643, when some twenty or more families from Yorkshire, England, who were wool combers and carders, settled in the town of Rowley in the Massachusetts Bay Colony They attracted wide attention for their proficiency in the production of woolen cloths This group later had the distinction of building the first fulling mill in this country Simultaneously groups settled in other parts of the country, developing in a decade a dominant

[1] A H Cole, *The American Wool Manufacturer*, Cambridge, Mass, Harvard University Press, 1926, Vol 1

household industry No marked alteration in this status was noted during periods of colonial history, which might have been because of the wool supply American Indians had no sheep and the first wool was supplied by the English A few animals were imported from England but they could not stand the rigors of the New England winter. In 1660 Parliament forbade the exportation of sheep from Great Britain This limitation of the wool supply continued until 1765.

The origin of American rug weaving is traced to the primitive Indians of the Pueblo tribe. Their weaving was an art which appears to have been handed down by the Spaniards when they arrived in North America. Women did most of the weaving, first tracing the pattern in the sand The fine textures, perfect workmanship, and glowing colors are seen at their best in some of these productions of the past

Early Household Methods and Equipment

It is interesting to note the technical equipment that the early American settlers contrived or had at their disposal The settlers had brought many of their implements with them from England, where the production of wool fabrics was a flourishing household craft in Yorkshire. In those days the grease wool was tub-washed and then prepared on hand cards and hand combs for the spinning wheel The hand cards were made like those of today, between two of them the washed wool was rubbed, paralleled or straightened, and mixed Bramwell[2] gives an excellent description of this procedure

The hand spinning wheel was used generally to spin the wool thus prepared It was a simple but tedious operation that was usually performed by the women or the older girls in a family The spinning wheel consisted of a spindle which was rotated by means of a cord passed around a large wheel that was turned by hand The "top" of wool was held in the spinner's left hand and fastened to the spindle The slubbing or unformed yarn was drawn out by a moving away of the hand. By means of the other hand the big wheel was set in motion and the spindle thereby made to rotate rapidly or slowly as required by the forming yarn causing the required twist to be put into the woolen or worsted yarn When a certain length of yarn was spun in this manner, it was wound around the spindle itself A foot pedal to operate the big wheel was commonly employed in flax spinning.

[2] William C Bramwell, *The Wool Carders' Vade Mecum*, Boston, 1881, page 130

equipment and methods evolved and at the disposal of the early wool home industry up to the year 1760

A Household Craft

Lack of statistical data makes it difficult to state to what extent the woolen and worsted trade was carried on in the early colonial period Transportation facilities, nearness to the coast or rivers style factors, importation of English cloths, and other considerations constantly changed the location of the production of wool cloths Governor Moore of New York in 1767 wrote[3] "The custom of making (these) coarse cloths in private families prevails throughout the entire province, and in almost every house a sufficient quantity is manufactured for the use of the family," but he added "without the least design of sending any of it to market" This proves that the industry was still a household craft and there were no signs of a factory system nor a systematic marketing of commercial cloths by groups Even with an increase in the transportation facilities and the growth of seaports after national independence was gained, the household production of wool cloth continued

The Fabrics by Name

Naturally, because of these considerations, there were few types of woolen goods The most important was "homespun," an all-wool fabric, well fulled, not piece-dyed but occasionally dyed in the fleece, and distinctly rough in character Another similar cloth was "linsey-woolsey," in which the warp was flax, which made it very durable It was valued at twice the price of homespun and was usually three quarters of a yard wide In the South a cloth of cotton and wool was made, which had no particular name Kerseys and flannels in very small quantities were the only other wool cloths produced at that time Broadcloth was unknown previous to 1760

Among the worsted cloths a diversity of fabrics existed in the early colonial days, these required a greater degree of professional skill but English- and Scotch-born weavers were among the early settlers and passed on their skills to their sons Among the worsteds were found serge, calimanco, drugget, crepe, camblet, all of them generally called "stuffs" and mostly made in imitation of foreign cloths The only worsted of American origin seems to have been the

[3] Eleanor L. Lord, *Industrial Experiments in the British Colonies of North America*, 1898, page 131

"tammies," a lightweight fabric used for dresses These were produced on a part household and part handicraft basis and not without skill Woolen or worsted cloths, according to most historians, did not enter into colonial or intercolonial commerce and were not sold in the shops, but they may have been bartered for other commodities

Early Colonial Legislation

Both governmental assistance and restrictions can be found in the early days of the domestic wool trade. Previous to 1700 and after 1640, cases are found where artisans such as weavers, fullers, combers, and artificers were offered acres of land in return for their services to a community or a colony In 1640 Massachusetts offered a bounty, to be given during a period of three years, for every yard of linen, woolen, or cotton cloth produced, provided it was spun and woven from wool or linen grown there. Acts against the export of goods and against the slaughtering of sheep were passed In 1675 exportation of grease wool was prohibited Other colonies enacted similar statutes Exemption from taxation was another form of encouraging woolen cloth making Encouragements of this type aided local communities but had no direct influence on the welfare of the colonies in general

A great deal of interference came from the mother country Wool manufacture was in fact the first of all others to be so restricted England's colonial policy was that the mother country was to work up the raw materials of the colonies and the latter to consume the manufactures of the mother country. The preliminary step in this direction was the disallowing by the British Commissioner of the Customs of two laws passed by Virginia in 1683 which prohibited the exportation of wool and granted bounties for the making of woolen and linen cloth in the colony. Parliament passed the so-called Woolen's Act of 1699 (prohibiting the export of, or intercolonial trade in, wool), but the act itself was harmless and its enforcement was even less effective After the passage of the Woolen's Act and within another year Parliament had enacted two more minor laws supplementary to the act One provided that no mariner nor passenger upon a vessel should purchase in the colonies more than forty shillings worth of woolen goods The other act abolished the export duties which had been in force on woolen fabrics exported from England in 1700 All this legislation served to stem any possibility of "setting up of Woollen Manufacture in the English plantations in America" However, the colonial wool industry had too

firm a root to be discouraged by such English legislation and continued to play a predominant part in the progress of the colonies

If the Woolen's Act had been more strictly enforced, there might have been serious conflict but, as it was, the domestic wool industry continued to grow in magnitude as a household craft during this period of political dependence Its growth was arrested only partially by the importation of English cloths and clothing, which were then better in quality and often undersold the local merchandise

1760—The First Small Factories

Following the slow development of wool manufacturing in the colonies, came a gradual transition from the household and handicraft system to that of the small factory The credit for the first attempt at a woolen factory goes to New England A wool-working enterprise was launched by Colonel Jeremiah Wadsworth at Hartford, Conn, in 1788 and was known as the Hartford Woolen Company The working capital was in part raised through popular subscription and is reported to have been £1,250 The patronage of the state was also enlisted · tax exemption for all property for five years and poll tax exemption for all workmen for two years helped to sustain this first American wool factory President George Washington visted the plant and ordered cloth, as did other prominent officials The equipment consisted of local looms, fulling mills, and some other finishing machinery In 1795 when this concern sold out its equipment it consisted of two carding machines, a spinning jenny, a twisting machine, and about eight looms Water power was employed Little is known about the jenny, which was probably worked by hand The carding machine is described as having two large main cylinders, with two doffers, and only two working cylinders, 16 inches in width It was said to have been invented by some person in the factory. Skilled labor and supervision apparently were very scarce Most of the wool worked came from domestic sources and most likely was very coarse, as no progress had been made in the quality of domestic wool although some had been imported from Spain The mill's product fell short of the quality found in imported fabrics, hence it had a hard struggle The company paid one dividend in cloth comprising a 50 per cent dividend on the original shares! There were 140 pieces of finished cloth still on hand when the factory was sold on the auction block One of the original promoters bought it, continued it for two more years, and then closed it down completely

Thus ended the first American wool enterprise, according to historians

Three more attempts were made to establish woolen factories, all of them in Massachusetts, one at Stockbridge in 1789, the second at Watertown in 1790, and the third at Ipswich in 1792 Little is known about the first two, but the latter concern was called the "Massachusetts Woollen Manufactory" It was promoted by John Manning, a physician, and was encouraged by town and state It produced broadcloth, blankets, and flannels It was later converted to the manufacture of cotton. The reason for these failures to establish an American wool factory were primarily the result of the peculiar character of the domestic market, competition with imported English fabrics, the poor quality of the wool supply, inferior technical equipment, and lack of skilled labor.

Beginnings of the Rug-and-Carpet Industry

The manufacture of rugs and carpets on a commercial basis was not established in America until after the Revolution In 1791 William Peter Sprague began to make Axminsters in Philadelphia, one of the first designs being a representation of the coat of arms of the new republic. It must be remembered in this connection that the Jacquard loom was not invented until 1801 It appears that the most important manufacturer of the early period was Isaac Macauley, who operated continuously from 1810 to 1837. He is credited with having made the first Brussels carpet in America

The first ingrain carpet mill in the United States was that of George Conradt, who came to this country at the beginning of the eighteenth century from Wurttemberg, settling in Frederick County, Maryland His carpets were made by hand loom on a drum studded with pegs, giving it the appearance of an enlarged, old-fashioned music box In 1804 Peter and Ebenezer Stowell opened a factory at Worcester, Mass, where they had in operation six looms of their own invention and construction, and thus acquired the right to the title of founders of the carpet industry in New England New York appears in the annals of domestic carpet history in the year 1821, when John and Nicholas Haight started a factory and employed as their mill superintendent James W Mitchell, a Scotsman from Kilmarnock, which was then the principal seat of ingrain manufacture in Scotland

First Improvements in the Wool Supply

Determined efforts were now made to improve American wool—"to render it more fit for superfine fabrics" The year 1793, when the Messrs Du Pont de Nemours and Delessert brought over a full-blooded ram named Don Pedro, can be taken as the beginning of better blood lines in American sheep Robert Livingston and David Humphreys, in purely national interest, brought in a flock of twenty-one Rambouillet rams and seventy-five ewes from Spain These efforts, however, wrought no immediate change or improvement in wool quality or quantity, although they caused a considerable increase in wool speculation and prices A merino "mania" set in during which as much as $1500 was paid for a single full-blooded ram Then, beginning in 1810, William Jarvis, the American Consul to Portugal, shipped over some 4,000 sheep Other importations followed in 1811, making a total of 25,000 imported merino sheep These animals laid the basis for a substantial supply of fine stapled wool The Du Ponts in 1812 had "perhaps the largest and best" flock of sheep in Delaware, and later erected three wool manufacturing plants themselves These sheep caused a wide-spread interest in wool growing and wool manufacturing Leicesters, Bakewells, and Culleys, English breeds, were also smuggled into this country and distributed in New Jersey, Massachusetts, Pennsylvania, and New York. In Virginia the flocks of Washington and Custis became famous

This movement for better wools and gradual increase in wool manufacture continued at a steady rate during the early twenties Fine Saxony merino sheep were brought in by Colonel James Shepherd of Northampton, Mass, in 1824, which resulted in an importation of some 2,000 sheep in 1826 By 1830, the quality of wool production of this country had reached an intermediate status, quite an advance over that in 1800, although very fine wools were still imported from Germany and Spain Traders and dealers in wool appeared all over the country and a wool warehouse was set up in Boston during 1814. All these influences in wool growing aided gradually the establishment of more and larger cloth factories

A Period of Machine Inventions

From the establishment of the Hartford factory in 1788 with its

crude, homemade machinery of unsatisfactory performance, until about 1830, a tremendous and remarkable advance in technical equipment in the American wool manufacturing industry was noted Within a space of forty years are found inventions and improvements of American origin which gave a new significance to the English power-driven carding machine, made the spinning operation practically semiautomatic, adapted power to the hand loom, and developed cloth-finishing operations so valuable that they were copied by foreign nations Most of these developments concerned the woolen branch of the industry, as the worsted branch was still of negligible proportions

In the conversion from carding by hand to carding by power, which occurred between 1748 to about 1790, Daniel Bourne, Richard Arkwright, and James Hargreaves of England made important contributions The introduction of the English inventions into America coincided with the immigration in 1793 of the Scholfield family to whom *The Hub* in its issue of December 1, 1873, gave credit as the first to manufacture wool by machinery.

It was in Newburyport, Mass, that the Scholfields built the first power-driven woolen card, which was about 24 inches broad and had a single cylinder. The machine is still preserved at the Davis & Furber Machine Company, in North Andover, Mass It led to the establishment of the "Newburyport Woolen Manufactory," where three of these cards were harnessed to water power At first, only the carding and fulling machines were power-driven Woolen broadcloths and flannels were manufactured In spite of the great potentialities of this new equipment, the concern failed after about ten years of struggle and was converted into a cotton mill Simultaneously, others set up cards of this character in Bunker Hill, in other parts of Massachusetts, and in Maine

The Scholfields exercised a tremedous influence in the wool manufacturing business and encouraged others to set up factories such as those in Montville, Conn ; Pittsfield, Mass , Stonington, Conn , Waterford, near New London, Conn ; Jewett City, Conn ; and at Dudley, Mass , in 1817, by various brothers of the Scholfields In 1812 was established the Nathaniel Stevens Mill in North Andover, Mass , of which Arthur Scholfield was superintendent Arthur Scholfield also entered the building of carding machines and the first advertisement offering such machines appeared on May 14, 1804. In 1806 he also built picking machines and in 1809 constructed spinning jennies Finally in 1814 he became one of the largest subscribers to the Pittsfield Woolen & Cotton Factory He died in 1827

Parallel with these developments, mechanical cards were set up at the towns of Leominster, Farmington, and East Chelmsford in Massachusetts In the latter town the card was operated by Moses Hale, the father-in-law of Nathaniel Stevens, who became a noted American wool manufacturer. The movement spread rapidly, and the incomplete census of 1810 gave the figure of 1,776 carding mills in the entire United States.

Further improvement of woolen cards came about rapidly through their wide diffusion These improvements—very minor in character—concerned the width of the card, which now reached 60 to 72 inches, and its construction, now partly of iron instead of entirely wood The most notable improvement was in the delivery of the carded wool, which heretofore was taken off in a sheet; now attempts were made to introduce a device of British origin, known as the "billy" or roping machine, between the carding and the spinning operations The function of the "billy" was to join the cardings together and to draw out or elongate the roping by giving it a little twist But the process was far from satisfactory and still resulted in yarn that was lumpy and weak.

As early as 1810 attempts were made to eliminate the "billy" but it was not until 1820 that John Goulding found a solution to the problem which resulted, in 1826, in the invention of the condenser in woolen carding, an important forward step in American woolen manufacture It was hailed by John L Hayes as "the most important of all contributions to the card-wool industry of the world" and by S. N D North as "almost as great an advance in wool manufacture as the spinning jenny itself" It finally eliminated the billy and the slubbing processes altogether, resulting in a roping of superior quality and a substantial increase in production It had its effect on spinning, in that where formerly jacks of 120 spindles per machine were employed, an increase to 200 spindles was possible with the condenser Introduction of the new apparatus was slow, the Pontoosuc Manufacturing Company in 1835 having only two condensers A firm in Worcester, Mass, in 1832 manufactured eighty-five such condensers for the woolen trade during that year. Goulding's device was introduced into France and Germany about 1839 but was not introduced into England until about 1859.

The spinning section of the American wool industry had a less obscure development, but it is not clearly defined in historic sources The spinning jenny made its first appearance in Philadelphia in 1775. It was used at the Hartford factory and the building of such ma-

chines was undertaken by the Scholfields. The first jennies were for family use and consisted of eight to fifty spindles The census of 1810 reported only 299 jennies for the whole country, and hence spinning was still a home industry. During 1815 the largest jenny reported, which was located in West Cambridge, now Arlington, Mass, had seventy-two spindles In the census of 1820 the number of spindles per jenny had increased from forty-four to 120 and in 1824 the largest jenny, reported to be at Uxbridge, Mass, had 150 spindles but was still hand-operated The Hockanum Company started the manufacture of woolens by making satinets (cloth of cotton warp and woolen filling) in 1814 at Rockville, Conn The application of power to the spinning of woolen yarns was apparently an obstinate problem which took years to solve It involved a transition from the jenny to the spinning jack, the first jack being set up by James Scholfield about 1802 at North Andover The next mentioned was one operated by water power in 1814-15 at Uxbridge, Mass, and another in 1819 at Peacedale, R I. In the transition from the jenny to the mule, historians mention Brewster's "globe spinner" of 1813 which, by 1824, became a real self-operating mechanism but came to naught Richard Roberts' self-acting mule, invented in England in 1825, became the model after which most power-driven spinning machines were patterned

Improvements in Weaving

Prior to 1830, hand weaving experienced several important improvements, namely, the adoption of the fly shuttle to the hand loom, wider reed space, and the gradual application of power to both wide and narrow looms The manufacture of fly shuttles started in Philadelphia in 1793 but was not immediately successful. The census of 1810 made this statement: "Though it (fly shuttle) has been known in this country many years, more than ninety-nine one hundreds of our shuttles are not of that description." Most households used narrow looms, rarely over 36 inches in width. With the introduction of broadcloths wider hand looms, which reached widths of 72 to 80 inches, had to be utilized. The Hartford factory had some broad looms and several others, such as the Housatonick Manufacturing Company of Pittsfield, had, in 1816, four broad and three narrow looms The first mention of a power loom to manufacture wool goods is of the one patented by Messrs. Shepherd and Thorpe of Taunton, Mass, in 1816 The census of 1820 lists eight power (waterpower) looms in a mill in Middlesex County, Conn.

The next decade brought a more rapid adoption of the power loom, particularly for satinets, which were quite popular Then came their introduction at Philadelphia and at Uxbridge, Mass, in 1821 and at North Adams, Mass, in 1822 But it was after 1825, rather than before, that the new mechanism came into general use for broadcloth weaving For flannels it was first adopted in 1824 at the Brighton Fair (Mass). In 1826 it was adopted for cassimeres and kerseys

Development of Finishing Machinery

In the finishing of woolen cloths, the application of power to two machines, the napper and the shear, marked an important development It started with the improvement of napping The first record of such a machine is that of Walter Burt of Wilbraham, Mass His patent, dated June 26, 1797, was a "gig mill" which employed teasels fixed in numerous small frames that were set in a cylindrical frame of about 2 feet in diameter The cloth passed over the "gig mill" sufficiently close to raise the nap and was wound around a cylinder below Somewhat later brass wires upon a cylinder were substituted for the cylinder of teasels; this machine came into use in 1812 at the Providence (R. I.) Woolen Manufacturing Company. The European countries are supposed to have copied this machine after 1802

The first mechanical shear was patented by S G Dorr of Albany, N Y., under the date of October 20, 1792 Called by the inventor "the wheel of knives" it consisted of a number of sharp blades at first placed parallel to the length of a cylindrical frame, but very soon (1793) arranged spirally, and worked against a stationary blade Others were invented by Beriah Swift of Washington, N Y, in 1806, William Hovey, his Ontario shear, Molleneaux, and Mussey Eleazer Sprague invented one, of which David Humphreys said "We judge this machine will shear as close and as smooth, at one operation, as our best English workmen would do at two with hand shears, and three times as fast at least; that one hand may tend three or four of them at once, when impelled by water—and thus the work of three weeks may be performed in a single day" This shear was frequently imitated in Europe and, according to historians, there is no question that with the mechanical shears the United States made a distinct contribution to the art of wool manufacture

In addition to these creditable advances in wool machinery before 1800, there were others, notably in warp dressing and cylindrical presses, that came as a result of developments in the domestic cotton industry, which had made great strides during this period

Gradual Growth of the Factory

A gradual diminution of household production and changes in quality of domestic manufacture with the development of distributive agencies in this country brought about the continued rise of the woolen factory. By 1836 a census taken by Benton and Barry reported 1,488 sets of woolen machinery in the United States, as shown in Table 1 The table shows clearly that in 1836 almost four fifths of the output was on fabrics of a distinctly medium and coarse character

TABLE 1

DISTRIBUTION OF MACHINERY BY CLOTHS MADE, 1836

Type of Fabric	*Sets of Machinery*	*Per Cent of Total*
Broadcloth	344	23 1
Cassimere	178	11 9
Satinet	574	38 5
Flannel	158	10 6
Linsey	210	14 1
Blankets, hats, yarns	24	1 8
Total	1,488	100 0

Source C Benton and S F Barry, *A Statistical Review of the Number of Sheep and an Account of the Principal Woolen Manufacturers*, Cambridge, 1837

The period of transition from a household craft to a full-fledged factory took place intermittently, the first step being carding and fulling on commission In such devious ways as by carrying out special processes, by manufacturing "on shares," and in supplementing and co-operating with the earlier household production, real factories began to crop up Gradually they grew and became able to stand alone, especially as the market for their product increased Mills advertised "arrangements to take in wool to card, spin or weave on shares" or "would card or spin on commission" The general tradition, which is apparent in numerous cases, was that the

American woolen factory found its origin in carding and fulling mills The factory, especially the weaving factory, did not evolve in one big movement and did not at once acquire self-dependence, but relied on outside help Gradually the idea of the independent factory gathered strength and breadth of action until the real beginning of the factory era about 1830. In the more western states, the woolen factories attained a position not unlike that of our more modern enterprises

During the War of 1812 the Embargo Acts, which shut off New England's foreign trade, made available great quantities of capital and turned the attention of financiers and business men to manufacturing During the war and up to 1815 the value of the manufactured wool products in this country more than quadrupled. However, the newly established woolen mills subsequently found it impossible to compete with the imported English merchandise, in spite of the protective tariff of 1816, which imposed ad valorem duties of 25 per cent on woolen goods and of 15 per cent on raw wool. By 1828 the period of trial and stress in the wool manufacturing business abated and a healthy recovery set in through better organization and improved manufacturing techniques A heavy duty on wool of 30 per cent ad valorem was applied except for wools valued at less than 10 cents per pound on which a tariff of 15 per cent ad valorem was made. Woolen goods were taxed 40 per cent in 1828 and 45 per cent in 1829.

The Factory Era—1830

In the next decade or so the factory had made a place for itself in American industry There was a distinct trend toward larger and more productive enterprises. Such factories as Samuel Slater & Sons at Webster, Mass, were operating on water power producing about 800,000 yards annually of broadcloth, cassimeres, and satinets and employing about 128 persons Among the well-known plants were the Hamilton Woolen Company, Pontoosuc Manufacturing Company, the Great Falls Manufacturing Company, the Middlesex Company, and others The erection of these mills marked the dawn of the new factory era. While power machinery had been invented, its introduction was slow and gradual. Fabrics better adapted to general American consumption were made, and steam power for mills was beginning to be considered seriously.

The next forty years of woolen manufacturing saw an increase

in population from thirteen millions in 1830 to thirty-nine millions in 1870 A rapid growth in transportation facilities, a steady westward extension, and a considerable tendency toward urban concentration added impetus to the growth of the industry In its own field of endeavor it saw a constant and more rapid decline in household cloth-making and also the initiation of the worsted branch of the industry As a whole, the expansion of the wool industry in the next forty years was indeed extraordinary. The woolen branch increased at least sixfold in terms of sets of cards While consumption of wool in 1830 was estimated as 14,500,000 to 15,000,000 pounds, it advanced to 189,000,000 pounds in 1869, a twelvefold increase

The growth of the woolen industry at this stage can be divided into two chief periods, beginning with that of 1830-1850 and continuing with that of the decade of the sixties, which includes conditions imposed by the Civil War The former was one of continued expansion and westward movement. Factories were established in Ohio and western Pennsylvania, one in Illinois in 1842, one at Milwaukee in 1847, and by 1856 mills had been set up at Cedar Rapids and Washington, Iowa, at Salem, Ore, and at San Francisco, Calif The figures given in Table 2 reflect this movement

TABLE 2

DISTRIBUTION OF WOOLEN MILLS IN THE UNITED STATES, 1837-1879

	Percentage of Establishments			*Percentage of Sets*		
Years	*New England*	*Middle States*	*All Others*	*New England*	*Middle States*	*All Others*
1837	—	—	—	60 6	34 6	4.8
1845	45 6	42.7	11.7	56 7	34 9	8 4
1849	30 9	45 9	23.2	—	—	—
1859	31 6	37 8	30 6	51 8	28.7	19.5
1869	21 0	26 9	52.1	40 1	27 9	32.0
1879	24 6	26 6	48 8	49 0	26.8	24.2

Of course, the growth of cities such as Lawrence, Worcester, Providence, and Philadelphia and the rise of the wholesale clothing trade had considerable influence. Another factor was the concen-

tration of facilities for raw wool purchase in which Boston played an important part. From one wool dealer and one warehouse in 1828, the business had grown to fifteen wool merchants located in Boston in the fifties As the years passed Boston became an ever-expanding center for the wool purchases of the entire country.

The worsted branch did not get a genuine start until about 1850, when the introduction of modern combing processes made worsted yarn manufacture commercially practical. The original worsted manufacturer in this country on a factory basis was the Dedham Worsted Company, which produced worsted yarn for coach lace, hosiery, and fringes Its development was slow and much delayed by an insufficient supply of long combing wool and a poor supply of skilled labor, in addition to the drawback that worsted manufacturing processes were not as yet adopted to power For wool combing hand labor prevailed to some extent until almost 1860 The Lowell Manufacturing Company engaged in worsted yarn manufacture in 1831 and the New England Worsted Company in 1845.

Comb Inventions

Dr Edmund Cartwright was the first in America to attempt to comb wool with mechanical power-operated machinery His first and second patents for a wool-combing machine were granted April 27 and December 11, 1790, and a third one May 15, 1792 By his method, three machines were required to prepare and comb the wool The principal features of the main comb, which was circular in form and revolved around its axis, were two or more devices to fill the teeth with wool (in much the same manner as it was lashed in hand combs) These devices consisted of rollers and cranks, a clearing comb, and drawing-off rollers Fine wool could not be combed on the machine, but it was fairly useful for combing coarse wools, although Cartwright was unable to devise any method of reducing the excessive production of noils

George E Donisthrop and his partner Dawson patented a machine for combing long, coarse wools in 1835 In 1842 they patented a machine that attracted the attention of Samuel Cunliffe Lister, a worsted manufacturer, who bought a half interest in the invention Several improvements were made and, in 1843, the firm of Lister & Donisthrop successfully combed Botany wool on power machinery for the first time in the history of the industry Further improvements were made and finally the firm adopted the principles of the

nip comb invented by Josue Heilman of Mulhouse, Alsace, France, and they were able to produce a well-combed top with a minimum quantity of noils

James Noble, a worsted spinner of Halifax, England, took out his first patent on wool-combing machinery in 1805, and twenty-eight years passed before he took out another His third and fourth patents for improvements in wool combers were granted to him in 1834 and 1835 While associated with Donisthrop, he was granted a patent in 1853 for a machine containing the principles of the Noble comb He is credited with having conceived the theory of two combs working one inside the other, but was unable to design a practical machine Donisthrop is credited with putting the idea into practical form by placing the circles concentric to each other, so that the teeth of both circles would come as close together as possible once during each revolution By fitting the external circumference of the inner circle with a gear that meshed with one on the internal circumference of the outer circle, he was able to make the inner circle rotate the outer In 1856 the feeding motion invented by Travenier, Croft, and Donisthrop completed the machine Donisthrop's name does not appear in any of the patent papers as inventor or co-inventor, as he had sold his interest in the wool-combing machinery to Lister, with the proviso not to engage again in devising new machines

Samuel Couillard, of Boston, devised an automatic combing machine for which he was granted a patent on July 7, 1835, and a second patent on June 16 of the next year On March 23, 1836, George Bond, Samuel Whitwell, H Rogers Kendall, and others incorporated the New England Worsted Company, with an authorized capital of $500,000, for the purpose of manufacturing yarn and cloth and building machinery The company began to build worsted machinery, including Couillard's comb, at Lowell, for the purpose of equipping a mill, but later moved its machinery to Saxonville, where the first wool-combing machine in the United States was put in operation The first product was worsted yarn for carpets, but the manufacture of bunting, which at that time was all imported, soon commenced and was conducted successfully for a number of years In 1845 the plant contained sixteen sets of woolen machinery and twenty combs, and the annual output was 350,000 pounds of worsted yarn for the market, 800,000 pounds of woolen yarn, 3,000 pieces of bunting, besides blankets, flannels, and negro cloth The New England comb, as the Couillard machine was called, received the wool direct from the card, to the front of which it was

attached It was used to comb carpet wools until after 1865, but it was not a satisfactory machine for combing fine wools. The progress of this branch of the business developed slowly owing to the lack of invention in the field of wool combing, which had been originated in France by Heilman

At about this time the newly formed Lowell Manufacturing Company began to manufacture cotton goods and carpeting at Lowell, Mass, and in 1828 the Lowell company bought the Medway mills, but operated them only until a new and larger mill was completed at Lowell, to which location the Medway machinery was moved Wright became the first agent for the Lowell company. Although their first product was "Lowell" ingrain, in due course they won recognition for Wiltons and Brussels and, later, for Axminsters

Technical Advances from 1830 to 1870

While technical progress previous to 1830 was extraordinary, that of the next forty years was more interesting and of greater significance It occurred primarily in the burring apparatus for wool in conjunction with cards, the improvement and increase in speed of looms, and the importation of worsted preparing and spinning machinery

The cleaning and scouring of wool underwent considerable changes While still done by hand in 1830, more scientific means and improved mechanical apparatus had been introduced The use of potash and soda soaps was becoming more general and a cleaner wool with less damage to the wool fibers assured better yarns and

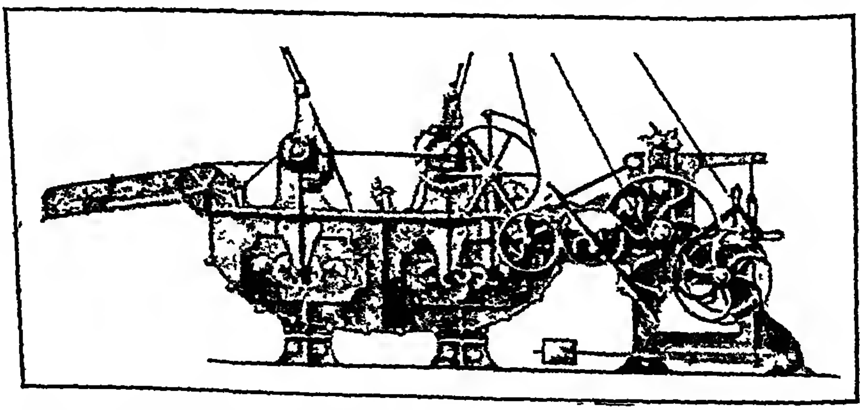


Fig 1. The first wool washer (1865). (*Courtesy C G. Sargent Sons*)

fabrics. The early large troughs or bowls in which the wool was soaked and stirred with long poles, were replaced by scouring machines

One of the first was the Sargent wool washer of 1865, made by C. G. Sargent Sons of Graniteville, Mass., shown in Fig. 1 It was one of the first labor-saving devices invented for the wool industry. The apparatus did the work more effectively, eliminated hand labor almost entirely, and fitted exceptionally well into American big production methods Sargent also pioneered in the mechanical burr-picking device (Fig. 2).

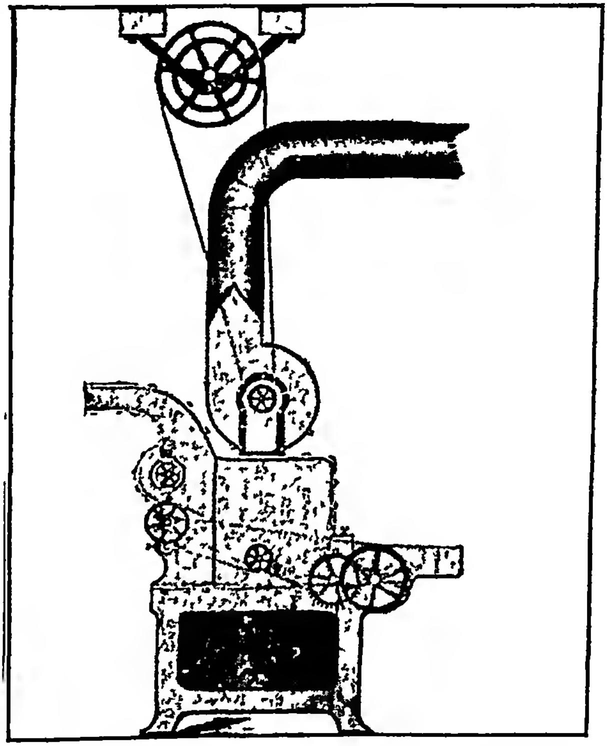


Fig 2 The first mechanical burr picker (about 1865) (*Courtesy C G Sargent Sons*)

In woolen carding appreciable changes occurred during the forty years following 1830 A general widening of 24 inches to 36 inches over the cards from the old Scholfield card occurred in 1830 The latter width remained standard for some time and was used in the Stevens Mills at North Andover in the fifties. Then it was increased to 40- and 48-inch widths and by 1890 half of the cards in American factories were of the 48-inch variety. Alterations in the intermediate feeds came about Heretofore, the product of the breaker and intermediate or second card was taken off in the form of a broad sheet of fibers It was wrapped on a roller and from that hand-fed into the next card Soon after 1830 an improvement called "side drawing" came about and permitted a greater mixing of the wool fibers. The wool fibers as doffed from the doffer of the breaker card were gathered and drawn to one side and passed through a revolving funnel

which smoothed the strand, imparting what is known as a "false" twist The sliver was then wound on spools, the operation being called "balling"

A frame containing a number (as many as forty) of these spools was set up before the feed end of the succeeding card, either intermediate or finisher This permitted more homogeneous mixing of the wool stock, resulting in a better roping from the finisher card and eventually in a better yarn This idea was invented by Robert Peele as early as 1779, but was applied to wool carding in America for the first time in the thirties, even before England used it

About 1850 the Apperly feed was invented in England and its construction and sale begun It consisted of forming the wool web as it comes from the doffer of the card, into a large rounded rope or sliver It was then guided to the feed apron of the next machine by an automatic device and laid upon that apron diagonally The Scotch feed was introduced not long after the Apperly and by 1870 it was a rather common appliance in English woolen mills

Advances were also made in the final removal of the wool from the finisher card Here the Goulding condenser had completed its conquest of the domestic field with many improvements, such as the substitution of rubbers for the older revolving tubes The first device was the "three-roll rub" introduced in the thirties It contained three pairs of rollers as wide as the card, covered with rubber between which the little ropings passed The rolls not only revolved forward but oscillated sideways at the same time An incidental draft with a false twist imparted smoothness and compactness to the roping, not hitherto obtainable by the revolving tubes In the thirties very few of these were made or used but the demand spread and by the middle sixties they were gradually displacing the revolving tubes In fact the Davis & Furber Machine Company was making them in 1865 in "three, five, seven and nine roll rubbers"[4] In these respects America was fully abreast of Europe Toward the end of this period Celestin Martin of Verviers invented the tape condenser, which was introduced in Europe in place of the Goulding The whole carding process was much improved in the decades preceding 1870, with particular emphasis on productivity and attainment of a better quality product

In the spinning of woolen yarns stagnation existed throughout this period as far as new improvements were concerned There was only the extension of the semiautomatic jack devised in the earlier period (1854). A model made by the Davis & Furber Machine

[4] Bulletin, 1901, page 269

Company was sold to the Ebenezer Society at Ebenezer, N. Y., which owned a woolen mill. It had 200 spindles, 1¼ inches apart and cost $300 with delivery in three months. Mules such as these were generally employed, although isolated instances are mentioned of imported mules from England This is in spite of the development of the automatic cotton mule by Richard Roberts in England in 1825 In 1860 the mule had been adapted to wool spinning in Europe Obviously, American industry failed to keep pace with foreign developments as far as wool-spinning machinery was concerned, the change to the automatic mule did not come about in America until after the seventies. This tardiness is attributed to several conditions in domestic manufacture

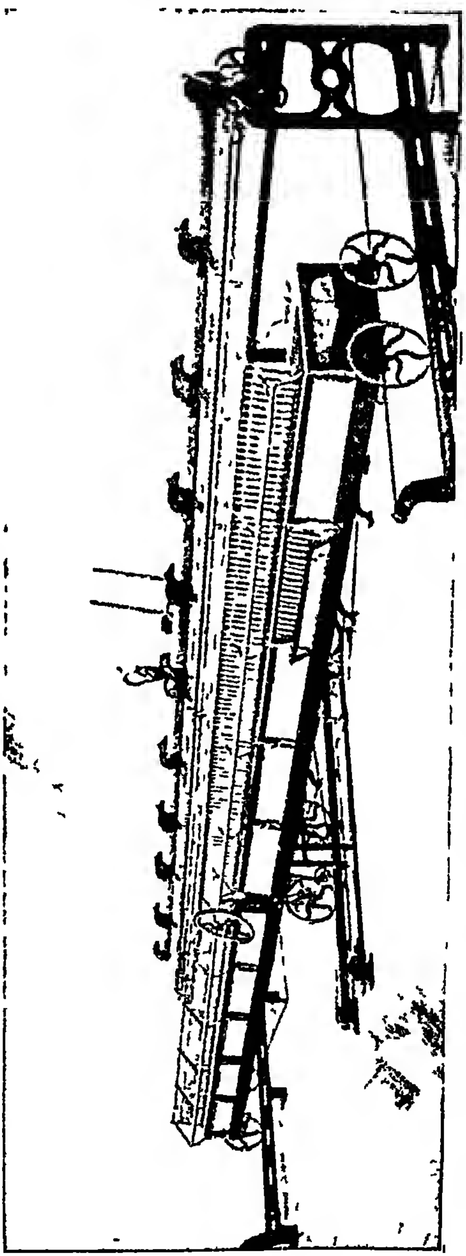


Fig 3 The first American mule spinner (1854) (Courtesy Davis & Furber Machine Company)

Worsted Branch Established

In the worsted branch of the industry, what little machinery existed was of foreign origin, particularly English, and mostly for the Bradford system. John L Hayes wrote in 1879 "In this department of the textile industry we have ex-

hibited less originality of invention or construction (than in the cotton and woolen branches) and have contented ourselves with copying or importing English and French machinery."[5] However, an increase in productive capacity was brought about by the introduction of the mechanical comb, the Simpson and Lister, in particular, as well as the Noble combs Thus, impediments which had stood in the way of extensive domestic manufacture of worsted yarn and cloth were removed in this period, and the course was already laid for the tremendous growth of the worsted industry which came about after 1870

Advance in Weaving to 1870

Cloth weaving received a tremendous impetus during this period from inventions which permitted more diversified output, as well as increased productivity of the weaving operation The first American iron power loom (Fig 4) was invented by William Crompton and patented in 1837. It was the first loom to employ the pattern chain and did much to advance woolen-cloth weaving on a diversified scale Previous to Crompton's invention, all woolen looms were cam looms, that is, looms in which the harnesses controlling the shedding of the warp yarns had been moved by revolving cams This meant a limitation on the number of harnesses, as well as patterns that could be woven without laborious rearrangement of the cams Both these disadvantages were overcome by the Crompton loom It enabled the production on power machines of more elaborate designs and weaves as well as patterns, with relatively little trouble in changing from one to another While first adopted for cotton weaving, it was a notable American achievement and was adapted to woolen weaving in 1840 at the Middlesex Mills at Lowell by William Crompton himself, according to Hayes It was then introduced abroad. "The significance of the invention to the American wool manufacturing industry as a whole," says Arthur H Cole, "may be appreciated from the fact that within a generation at least three quarters of all the woolen cloths then worn had come to be woven on these fancy looms"

The Congressional Committee on Patents heard it stated in 1878 that: "Upon the Crompton loom, or looms based upon it, is woven every yard of fancy cloth in the world" The loom also had its effect on the production of American woolen cloths such as the fancy cassimere The proportion of sets devoted to cassimeres in New

[5] John L Hayes, *American Textile Machinery*, Cambridge, 1879, page 53

England and New York more than doubled between 1837 and 1860. In Massachusetts alone the yardage of such fabrics rose from a little under 2,500,000 yards in 1845 to nearly 15,500,000 yards in 1865, and cassimere became the outstanding cloth in American production

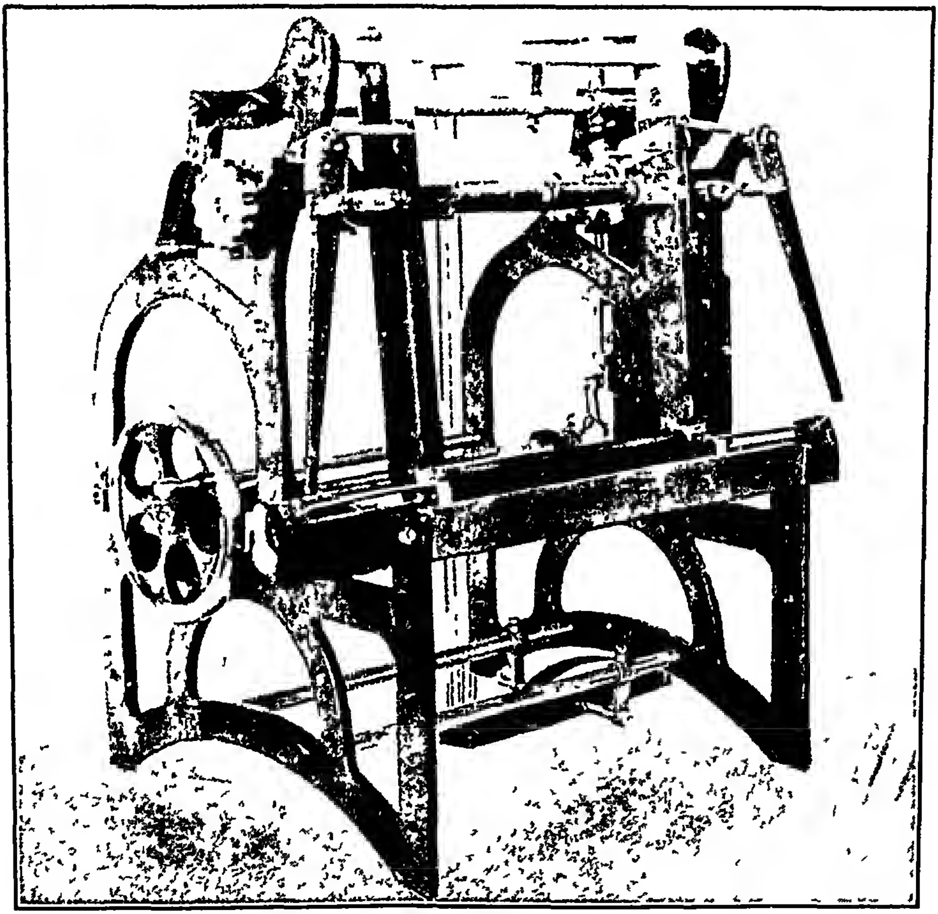


Fig 4 The first mechanical power loom
(*Courtesy Crompton & Knowles Loom Works*)

Because Crompton's loom was only 40 inches wide, its speed limited to forty-five picks per minute, and contained provision for

only *one shuttle,* it was, of necessity, rapidly improved. The first improvement was the adding of shuttle boxes, first on one side and then on both sides, permitting the "mixing of the fillings" and the use of more than one color of weft yarn In 1857, Crompton developed his broad fancy loom, which permitted not only the weaving of 54-inch woolens but also increased the number of harnesses to twenty-four with three boxes at either end Still more important was the increase of the speed from forty-five picks per minute to eighty-five picks per minute By 1870 the loom had been still further improved, not only by better workmanship but also in rendering it more nearly automatic and capable of still greater production. In this development Lucius J Knowles played an important part In 1863 he patented the "open-shed" loom in contradistinction to the "closed-shed" looms of Crompton Under the "open-shed" system, a harness once raised is maintained in that position during perhaps two or three picks until the demands of the pattern chain require its depression The loom was particularly suited to woolen-yarn weaving, because such yarns are weak as compared to most textile yarns and the open shed meant a relief of an appreciable amount of strain, especially on the warp yarns

An important advance made in this period was made in the finishing department and was the shift from the old wooden block method of printing to that of the roller method Printing by roller was first done at the Hamilton Woolen Company shortly before 1860.

Another significant trend to be observed was the establishment of a specialized machinery building industry to serve the wool textile industry Heretofore, small mechanics or the village blacksmith or carpenter were called in to do special building or repairs With the development of more complicated and heavier *iron* machinery, a distinct change-over set in The Crompton & Knowles Loom Works, the C G Sargent enterprise, and the Davis & Furber and the Smith Woolen Machinery companies are examples in their respective branches

Early Beginnings of the Carpet Industry

George W. Lyman, who was treasurer of the Lowell mill from 1831 to 1841 when power looms were beginning to show promise of real success, gave much encouragement during this period to a young inventor named Erastus B Bigelow. Lyman also provided Bigelow with financial aid from time to time. Orrin Thompson, in 1828, was

granted a charter to manufacture ingrain carpets at Thompsonville, Conn , as the Hartford Manufacturing Company Despite the fact that 1828 was a disastrous year for business generally, under the guiding hand of Orrin Thompson the Hartford company prospered Commencing operation with fifty hand looms, the company weathered the financial panic of 1832 and in 1833 erected a new factory Shortly thereafter the first three-ply ingrains ever made in this country came on the market Fifty additional looms were put into operation in 1841, and in 1842 the manufacture of Brussels was undertaken on forty-one new looms Moquette, a fabric similar to the present Axminster, followed, and in 1845 the total number of looms had increased to 250, five times the original equipment

In 1840 Thompson organized the Tariff Manufacturing Company, purchased a factory at Tariffville, installed Bigelow power looms, and continued operation of the Thompsonville mills In 1854 the Hartford company was reorganized and in 1859 the Hartford company bought the factory at Tariffville

The foremost genius of the industry, Erastus B Bigelow, was born in 1814 at West Boylston, Mass At twenty-four years of age he invented a machine to weave coach lace which embodied the principles which he later developed into the Brussels carpet loom His coach lace business prospered almost from its start, in 1838

In 1848, he subsequently developed the most complicated of all his inventions, the Brussels automatic carpet loom He also produced variations of his invention to weave Wilton and tapestry velvet carpets, specimens of which were shown at the London Exhibition of 1851 and cited as being "better and more perfectly woven than any hand-loom goods"

At this time the product of a day's work of ten to twelve hours for a weaver, including a boy to draw the wires, was 7 yards of Brussels Bigelow's loom made over 25 yards of a superior two-ply fabric In 1849 power looms were set up and in 1851 there were twenty-eight of them in operation, producing 500 yards of Brussels daily Prior to the perfection of his invention in 1849, Bigelow formed the firm of H N & E B Bigelow, and his company had the honor of operating the original power factory devoted to the manufacture of Brussels and Wilton carpets This business was incorporated in 1854 under the name of the Bigelow Carpet Company and continued in operation until 1899 when it united with the Lowell Manufacturing Company to form the new Bigelow Carpet Company

In 1841 carpet manufacture in the United States was an infant in

every sense of that term There were seven factories in operation in Massachusetts, four in Connecticut, eight in New York, and four in New Jersey In Pennsylvania there were five, all in or near Philadelphia, Maryland had one There were approximately 800 looms in operation in the several most important mills Among those in operation at that time were the first plants of several of the largest concerns now in the trade, including Robert Beattie & Sons

American Wool Supply and the Tariff

The injection of better blood by the Spanish merino and the Saxony merino crazes did not improve the American wool supply sufficiently to make it better or even as good as the quality of imported wool The staple was somewhat longer but only of medium fineness and it was not as yet suited to the production of the best broadcloths Henry S. Randall points out that Saxony merino wool paid best during 1831-37, but after that the price favored the American merino and the Saxony merino was abandoned The number of merino sheep decreased in Massachusetts between 1837 and 1845 from 47,000 head to 34,000 head [6] This decrease can be attributed to the growing demand for mutton The substitution of Argentine wool was not entirely satisfactory because it was distinctly inferior to the representative European wools The situation in the wool supply was becoming progressively worse, especially for the manufacture of broadcloths

To this was added the tariff situation, which is summarized in Table 3 Under preceding tariffs it had been customary to provide appreciably higher rates for wool manufactures than for the raw fiber Thus, in the immediately preceding act, that of 1842, while wool valued at less than 7 cents a pound—including almost all of the La Plata wools—was dutiable at only 5 per cent ad valorem, wool manufactures with some exceptions, such as blankets, bore a duty of 40 per cent The tariff of 1846, however, eliminated this gap in rates, both raw wool and wool manufactures were included in the same schedule and taxed at the single rate of 30 per cent Under the preceding tariffs of 1824 and 1828 the protection had not been appreciably greater, yet the substantial decrease afforded by the act of 1842 probably contributed to the decline of broadcloth or fine goods manufacture, which depended for its success largely on a high tariff protection.

[6] Chester W Wright, *Wool Growing and the Tariff*, Boston, 1910

TABLE 3

WOOL TARIFFS—1816-1867

Date of act (and when effective)	Rates of duty on wool imports
1789 1816	Free
Apr. 27, 1816 (July 1, 1816)	First act 15 per cent ad valorem
May 22, 1824 (July 1, 1824)	Value of 10 cents a pound or less, 15 per cent, other wool, 20 per cent until June 1, 1825, 25 per cent until June 1, 1826, 30 per cent thereafter
May 19, 1828 (Sept 2, 1828)	4 cents a pound plus 40 per cent to June 30, 1829, plus 45 per cent to June 30, 1830, plus 50 per cent thereafter
July 14, 1832 (March 4, 1833).	Value of 8 cents a pound or less, free, other wool, 4 cents a pound plus 40 per cent.
March 2, 1833 (Jan 1, 1834)	Duties exceeding 20 per cent to be reduced to 20 per cent by yearly reductions to July 1, 1842
Sept 11, 1841 (Oct. 1, 1841)	All rates below 20 per cent to be 20 per cent
August 30, 1842 (August 31, 1842)	Value of 7 cents a pound or less, 5 per cent, other wool 3 cents a pound plus 30 per cent
July 30, 1846 (Dec. 2, 1846)	30 per cent.
March 3, 1857 (July 1, 1857)	Valued at 20 cents a pound or less free All others, 24 per cent
March 2, 1861 (Apr 2, 1861)	Value of 18 cents a pound or less, 5 per cent, value over 18 cents to 24 cents, 3 cents a pound, value over 24 cents, 9 cents a pound
June 30, 1864 (July 1, 1864)	Value of 12 cents a pound or less, 3 cents a pound, value over 12 cents to 24 cents, 6 cents a pound, value over 24 cents to 32 cents, 10 cents a pound, plus 10 per cent, value over 32 cents, 12 cents a pound plus 10 per cent Scoured wool, three times these rates
March 2, 1867 (March 3, 1867)	Class 1 (clothing wool), value of 32 cents a pound or less, 10 cents a pound plus 11 per cent, value over 32 cents, 12 cents a pound plus 10 per cent Class 2 (combing wool), value of 32 cents a pound or less, 10 cents a pound plus 11 per cent, value over 32 cents, 12 cents a pound plus 10 per cent Class 3 (carpet wools), value of 12 cents a pound or less, 3 cents a pound, value over 12 cents, 6 cents a pound Washed, Class 1, twice these rates, scoured, all classes, three times these rates

Source U S Department of Agriculture, No 894, page 305 (in part)

Fabric Importations

In this period the importations of various woolen and worsted fabrics played a more important role than at any other time in American history. On the one hand, it was in this period that the domestic industry could, for the first time, effectively resist the hitherto unrestricted inflow of foreign goods, on the other hand, it was the first time that the domestic industry had to face competition other than that of British imports

Around 1830 cloth importations formed something like a fifth of the total wool cloth supply of the United States, whereas, in 1849 and 1859 (the first census figures), it constituted about 29 and 34 per cent respectively. Even in 1869 foreign goods still formed

about 25 per cent of the total domestic consumption. It was not until 1860 that importations of foreign goods declined and kept declining. The war, the tariff, and the rapid perfection of European techniques during this period combined with the slow progress of the United States toward the production of fine wools and goods, made this period one of the most serious threats to domestic manufacture from the inroads of foreign competition

During the greater part of this period England had been practically the sole supplier of wool goods to the American market By 1830 England was shipping 80 to 85 per cent of the total importations Germany came to the front in 1850 with shipments of "cloths" and yarns which amounted to 15 per cent of the total import of such goods, by 1860, German imports reached 24 per cent and by 1870, 38 per cent, percentages for such goods which were not subsequently exceeded Quoting the New York *Tribune's* account of the Exposition in 1853 at the Crystal Palace. "Messrs Forstmann & Huffmann, Werden-on-Ruhr, Prussia, are large manufacturers for the American market So well known are their goods, that they are commonly called F & H goods, and are considered to be among the best of the foreign goods brought to America" Germany in 1860 and 1865 also supplied over 70 per cent in value of woolen and worsted yarns, a less important item, however France, for a time, threatened severe competition and by 1850 she was sending over one fourth (in value) of American imports of wool cloths, an amount which dwindled to 5 per cent by 1870 However, England still held a dominant position, particularly in stuffs, i e, dress goods and blankets In 1865 England sent 85 per cent of all dress goods imported In 1870 the percentage declined to 80 per cent

While linsey-woolsey, flannel, homespun, and perhaps some of the lighter satinets were offered by the earlier domestic producers, worsted fabrics had begun to come into greater demand Although the manufacture of lightweight fabrics of the dress goods type was slow in developing, with the rise of delaine and similar manufactures in the forties and fifties, a small supply of dress goods from domestic sources became available The American industry, however, was deficient in mohairs, luster wools, cashmeres, and the like This situation persisted even after the Civil War The American industry was handicapped for many years The free entry of Canadian long wools under the reciprocity treaty in 1854 came to an end in 1866, delaying progress in this direction In fact, it was not until 1897 that a marked increase in such importations occurred

Thus imports, while still considerable, did not threaten to increase and, in the strengthening of techniques during this period, the woolen industry had a gambling chance to still further curtail imports The young worsted industry, established in this period, was of questionable strength and reflected the drawback of the heavy foreign shipments Its future was indeed uncertain, but it was set for the astounding progress scheduled for the next twenty years

In 1864 on the fifth of October at 12 noon a meeting was called in Springfield, Mass, at the Massasoit House for the purpose of forming a National Association of Wool Manufacturers The circular was signed by thirty-six manufacturers and issued in August of that year The meeting was attended by representatives of 123 establishments operating 1,139 sets of machinery The organization of the Association was effected on November 30, 1864 and the by-laws adopted The first *Bulletin* of the Wool Manufacturers was established and has been continuously maintained since that time The formation of the Association was an important step on the part of the industry to act in a united and systematic manner on problems of industrial and national character

The Industry in 1870[7]

The foregoing discussion has traced the development of American wool manufacture in its various aspects during the period 1830-1870 Accordingly, there is reason to pause before entering upon an analysis of the more recent decades, in order to survey the advances which were made in the forty-year period before 1870, and to ascertain more generally the real situation in the latter year In what chief features did the American wool manufacture of 1870 differ from that of 1830, and what were the tendencies of the development?

The factory had reached maturity by 1870 As an industrial form, the wool factory in 1830 had been a new phenomenon, and in many ways had showed this status Frequently, the newly sprung up mills had relied upon outside aid of various sorts to carry on their operations If they did not commonly employ labor outside their walls, they often supplemented their own manufacture by taking in carding, spinning, and other work from quasi-household producers Nor were cases rare in which the mills depended largely upon the strictly

[7] Arthur H Cole, *The American Wool Manufacture*

local markets, sometimes even exchanging finished cloth for wool or other supplies By 1870 this situation had changed For a large and growing section of the industry—that is, barring the western mills—establishments were as self-dependent as they are today. The transformation of greasy wool into finished fabrics was carried through wholly inside the factory walls, the disposal of production was achieved through a broad and well-organized marketing system

The period 1830-1870 was an era of real growth—a growth perhaps not so striking as in the decades before or afterwards, yet very substantial In view of difficulties such as lack of standardization and tariff conditions existing throughout this period, the industry's advance during this time was indicative of its vigor.

Growth of the Carpet Industry

About 1856 Alexander Smith was making carpet in a factory at West Farms, N. Y and conceived the idea of weaving Axminster, or tufted, carpets on a power loom He employed Halcyon Skinner to devise a loom About a year later one was constructed and patented, but it proved unsatisfactory In 1860 another loom was built which was successful In 1864 the Smith factory was moved to Yonkers, N. Y, and engaged in the production of ingrain and, subsequently, of tapestry Brussels on a larger scale Skinner continued in the employ of the Smith Company and improved the ingrain looms and machinery for tapestry Brussels manufacture In 1876 he invented a power loom for making moquette and in 1877 obtained a patent on the device Later this loom was improved by the inventor and still further perfected by his sons, Charles and A L Skinner

James Dunlap of Philadelphia merits more than honorable mention for the method which he devised and patented in 1891 for printing tapestry carpet in the cloth Dunlap's process included the use of a peculiar roller which not only gave the fabric a superficial color, but also held the dye in cells or depressions, so that when the roller was applied to the carpet under high pressure the coloring matter was forced down to the roots of the pile and thoroughly saturated them This process was improved by Dunlap in 1896 Robert Beattie & Sons were pioneers in manufacturing Smyrna rugs in the United States At first, about 1880, they made them by sewing together breadths of chenille carpet and then sewing on a border which was woven with separate corner pieces to avoid mitering

The goods were made in one size, 6 by 9 feet, and sold as "Turkistan" carpets.

For three quarters of a century Philadelphia was famous for her production of ingrain and Venetian hall and stair carpets. Tremendous growth did not begin until after the Civil War, and about 1870 there were 215 factories, large and small, turning out great quantities of carpets Shortly afterward power looms began rapidly to replace the old hand looms and gave a great impetus to the trade In 1895 ingrain was at the height of its popularity and thereafter its production showed a steady decline until today, when it ranks last among the well-known types of carpet It remained for the Philadelphia house of Hardwick & Magee Company, 1893, to make successful a novelty which was destined practically to revolutionize floor-covering methods

At the crest of the great ingrain wave, there were in Philadelphia 3,300 looms with a capacity of 45,000,000 yards annually, more than that of the other carpet factories of the country combined. United States Bureau of the Census statistics tell the story of the growth of the industry in Philadelphia in a brief but none the less emphatic manner They show that in 1850 the value of production was $1,137,000, in 1870 it was $9,625,000, and in 1890 it had grown to $21,504,000

The present day Firth Carpet Company was established in the United States by members of the firm of T F Firth & Sons, Ltd, of Heckmondwike, England In 1886 they purchased the Broadhead Mills at West Cornwall, New York, manufacturing Axminster, velvet, and tapestry rugs and carpets. They purchased the American Axminster Industry, making seamless chenille, and continued operation of the plant facilities formerly developed at Auburn, N Y. The Mohawk Carpet Mills, one of the largest organizations in the industry today, was incorporated in 1920, in New York, as a consolidation of two firms which had been in the carpet manufacturing business for two-score years Shuttleworth Bros & Co, which was established in 1885, and McCleary, Wallin & Crouse, founded in 1886, under the firm name of Howgate, McCleary & Company McCleary made seamless chenille rugs and carpets

Improvement in the Wool Supply

Worsted manufacture in the United States was stimulated largely by the acquisition of the long, lustrous Canadian wools from the English breeds of sheep and by the Reciprocity Treaty of 1854-1865

It was this latter factor which gave impetus and encouragement to the local worsted manufacturer, plus the rising protective rates on wool manufacturers during the early sixties The treaty's abrogation, of course, came as a distinct blow and the industry was again seriously handicapped

Modification and constant improvement in the wool-combing operation, especially in the Noble comb, brought about the utilization of a much shorter staple than the Lincoln and Leicester fleeces, so that wools of 2½ to 3 inches could be used This enabled the worsted manufacturer to operate not only on the cross-bred fleeces but also on a good part of the merino staples The former, which varied in length from 4 to 6 inches and were entirely wools of quarter and half-blood character used for worsted coatings, formed the basis of the future growth of the American worsted industry. The wide utilization of pure merino wools in combing came much later It afforded an opportunity for progress, which was quickly realized by the manufacturers and resulted in an almost complete revolution of the worsted branch and for a time (between 1879-1889) medium-grade domestic wools sold regularly at higher levels than fine wools Importations of wools from England during that period fell from the high of about £50,000,000 in 1873 to less than £6,000,000 in the decade of the eighties As a result of this decrease, new American fabrics were devised, differing from the old, bright, cotton-warp "stuffs" hitherto produced Not only did all-wool men's-wear fabrics come into vogue but also soft dress goods for women's wear, resulting in the development of keen competition with the older woolen fabrics

In conjunction with this change in wool demand by the worsted branch of the industry came an increased demand for mutton However, the merino was not a mutton sheep and the English breeds of sheep did not have the adaptability or wide usefulness of other wools Hence, crossbreeding was resorted to by sheep-growers A mating of a Leicester ram with a merino ewe was first performed, yielding a half-blood animal with a mutton carcass and a fleece resembling both parents somewhat Subsequent interbreeding yielded various intermediate grades, designated as three-eighths blood, quarter blood, and so forth By reason of crossbreeding, the wool came to be better suited for the combing operation, an important element in its advance. This brought greater prominence and importance to the crossbred animal in the chief wool-producing

countries. It effected great changes in the Middle West after the Civil War, which has been in recent decades the largest American wool source. Meat refrigeration, an innovation which came about in the early eighties, helped to bring about this change in Australia, South America, New South Wales, and Argentina, with the result that the entire world's wool supply tended in the same direction as America's.

As time went on a demand for finer worsteds and finer wools came about with the gradual return of merino wool At about this time, fine and medium-fine stock was reported of considerable importance in worsteds Hence the delaine wools, which are the best type of merino combing wools grown in the United States This type of wool was obtained from the north-central region of the country—Ohio, western Pennsylvania, West Virginia, and so on After 1870 the "territory" wools also increased in importance as transportation facilities in the far west grew or improved. But these wools did not at first prove to be of sufficient length to permit combing, although later a fairly large proportion was being utilized in worsted manufacture The older Bradford system of worsted yarn production, using the Noble or other British combs, could not utilize wools less than 2 to 2½ inches in length, but the introduction of the French system upset this situation because, by means of the Heilman comb, it could employ wools as low as an inch in staple and of weaker character The improved technique of the Bradford system, as well as the acquisition of the French worsted system, both acted to create competition within the wool market With the development of the worsted branch the worsted manufacturer dominated the wool market as the woolen manufacturer came to use more noils, wastes, shoddy, and reworked fibers While cotton warps had been used since the days of the satinets, recovered wool fiber or shoddy was first used in the eighteen-thirties in small quantities Its use increased from an unknown quantity to 19,000,000 pounds in 1870, according to Cole

Wool Marketing Centers

In 1870 Boston was the leading wool market and it continued its prominence in the storing, concentration, and trading of imported

and domestic wools In 1869-1871 Boston handled a little over 35 per cent of all imported wools, and in 1886 secured 56 per cent of such wools This increased later to over 72 per cent just before World War I Summer Street, Boston, became the place where wool buyers and dealers congregated from all parts of the world and is now well known in wool circles

In 1870, Boston took care of 35 to 40 per cent of the domestic wool clip and just prior to World War I it was receiving 70 per cent of the clip Nowadays, little trading in wool is done outside of Boston, Philadelphia, and Chicago New York's prominence is as a carpet wool and wool substitute market Chicago is a leading pulled wool market, Philadelphia a carpet wool market The reasons for Boston's prominence in the wool trade have been excellent banking facilities and good port and storage facilities, it has the largest wool warehouse in the country, which can store a third of the ordinary domestic wool clip New England mills are fortunate to have such a center, which permits them to make quick, advantageous, and easy purchases, requiring little stock or storage, and by which they can follow the market closely and cut down expenses in sending buyers to all parts of the sheep country Specialized houses or distinct departments enable the buyer to select his wool or substitutes on inspection of relatively small quantities or even samples.

In review, the period since 1870 has witnessed a broadening of the range in wools acceptable to the worsted industry, accompanied by certain changes in the general character of the world's and, incidentally, of American wools, which tended to favor the latter The woolen branch of the industry has had recourse to a greater use of wool substitutes—a feature tending to complicate the conditions of that section of the trade A noteworthy betterment and a greater localization in wool dealing has taken place arising out of the tendency toward centralization of the manufacturing industry, which has given stability and maturity to the industry as a whole and has distinctly favored the forthcoming large-scale production of woolens and worsteds

Technical Advance After 1870

While the factory system began in 1830 and had blossomed following setbacks to fairly large units in some parts of the industry, a greater development in the diversity of cloth fabrication was yet to come The changes that occurred in technical equipment after

1870 were largely the result of alterations of the techniques and advances in the quality of domestic cloth production, these changes occurred with the spread of large scale manufacture of medium quality fabrics and, later, an increase in fine worsted fabrics, though on a [illegible] highly productive basis, came about.

The improvements in technical equipment centered around the origination of new machinery, the type of change created, and the degree of advance over existing apparatus. In wool scouring, both woolen and worsted, constantly larger units were built, even larger than those developed in Europe. Burr removal was not very important since American wools were free from burrs for the most part, hence this operation was developed more extensively on the Continent. The burr picker, an American invention, as well as the burr cylinder attached to the cards, were generally sufficient for the elimination of vegetable matter from our wools. For the very burry wool, chemical carbonization was resorted to, a process invented by Gustav Koeber of Germany and introduced there about 1850 or 1860. Burry wools were usually wools of a high shrinkage and this factor, together with high import duties, contributed to disinterest on the part of American manufacturers in the chemical methods. Hence, carbonization was introduced here very gradually.

The Worsted Industry After 1870

The introduction in America of worsted coating manufacture brought about many adjustments in the character of the machinery, which was mostly imported. The Bradford system was used first and practiced after its English pattern, the machinery remaining essentially the same. The Continental system, also known as the French system, was introduced in the eighties and nineties and the machinery was largely imported. The importation and presence of foreign foremen and mechanics aided this movement and the industry. Worsted spinning machinery for the Bradford system was not built locally until 1898 and the French system machinery continued to be imported.

The tendency, so pronounced after 1870, toward larger and more productive machinery brought about general adoption of the Noble comb, the capacity of which was greatly increased during this period. The massiveness and nicety in construction of the Bradford spinning system, as well as the size and number of the spindles per frame, were greatly increased. Spindle speeds were increased from

5000 r p m to 7000 r p m Cone drawing, as practiced by the cotton-spinning plants, was soon introduced into American worsted spinning The tendency of all improvements was toward greater mass production and toward making the manufacture practically automatic from start to finish In spite of the fact that the French system was the more recently introduced and attained its greatest development after 1870, the Bradford system enjoyed a continuous growth because of its greater productivity and cheaper cost Practically all the capital and machinery for the French or Continental system were foreign and had to be imported and no attempt was made to create such machinery here, as was the case with the Bradford machinery The Noble comb had been substituted extensively for the French comb Drawing machines and spinning mules were made larger and more productive as well as more solid in construction As a whole the worsted industry experienced a general and sudden upswing in production beginning about 1889 and lasting until 1909, when it reached its maturity with increases in wages earned of 860 per cent and in quantity of raw materials consumed 1,925 per cent By 1909 the value of worsted products was over fourteenfold that in 1869 Indeed a most striking progress!

Techniques in the Woolen Branch

In the woolen branch, the great desire for larger productivity brought about larger machines, increased intensity of operation and, most important of all, resulted in the introduction of labor-saving devices While in 1870 the majority of cards were 48 inches wide, in 1890 the 54-inch, 60-inch, and even 72-inch cards made their appearance, with consequent greater production They constituted more than 87 per cent of the domestic equipment In this respect American manufacturers progressed faster than their European competitors, particularly in card speeds Probably the most outstanding developments were in the carding accessory field, such as automatic feeds, intermediate feed and transfer devices, and the final condenser, on which substantial and consistent progress had been made since the time of the Civil War The Bramwell feed, an American invention introduced just prior to 1870, was adopted by the entire domestic industry Today it is employed abroad as well as in American mills For intermediate feeds, the Apperly feed, invented abroad, is used extensively in American mills

These two devices eliminated much labor and made the three-card system of woolen carding practically automatic Concerning the finisher card, the most important changes in this period came in the condensing end. While the American industry stuck pretty well to the Goulding form of condenser—ring doffer and the rest—satisfactory improvements in application such as apron and roller rubbers and systems of multiple rubbers, were made which augmented their effectiveness The number of ropings was increased and, as a consequence of the whole development, a finer woolen yarn could be spun.

The tape condenser, a Belgian invention of the middle sixties, was not introduced in this country to any appreciable extent until World War I In this system the broad web of carded wool fiber is drawn off the final doffers of the finisher card by close-running leather belts, ½ to ¾ inches wide, as a large number of narrow bands which are rubbed together into ropings similar to those obtained from the older, ring-doffer system

In woolen spinning, important changes have taken place since 1870. In 1870 the hand jack was still employed and the earliest attempt at improvement was the endeavor to render the semiautomatic hand jacks completely automatic by the elimination of the well-known jack spinner Attachments to the hand jack, by means of which this apparatus could be made wholly automatic,[8] were brought out by several inventors in 1869-1871 While a distinct advance, they were not wholly satisfactory The English mule, developed in the preceding period, was being imported in goodly numbers and eventually in the eighties replaced the old jacks entirely. This change meant much to the progress of the domestic woolen industry and had great significance, first, because the hold of the jack spinners upon the industry was broken, and second, because it marked the conquest by automatic machinery of the last important section of the woolen industry. Wool sorting and burling remained hand operations and probably never will become automatic.

While progress was also made in winding, warping, and twisting, historians find available information about these processes less abundant and reliable. It then remains to consider the progress in weaving during the period after 1870. American manufacturers clung steadfastly to the Crompton & Knowles looms, which have been improved constantly In 1857 the speed of the loom was raised from 45 to 85 picks per minute, a great advance, and was

[8] Arthur H Cole, *The American Wool Manufacture*, Vol II, page 89

gradually raised to 100, 110, and 125 picks per minute as the nicer attachments and refinements went on The highest speeds were attained in worsted weaving, while woolen looms held to 90 to 105 picks per minute The Crompton fancy loom was a broad machine and the tendency toward wide goods continued after 1870, as indicated in Table 4 The distinct trend from narrow to broad

TABLE 4

PERCENTAGE OF BROAD AND NARROW WOOLEN AND WORSTED LOOMS

	Woolen Looms			Worsted Looms		
Year	*Broad*	*Narrow*	*Hand*	*Broad*	*Narrow*	*Hand*
1869	41 1	58 9	—	—	—	—
1879	45 4	53 0	1 6	22 0	76 4	1 6
1889	53 3	45 9	0 8	42 5	57 2	0 3
1899	61 0	38 9	0 1	63 7	36 3	—
1909	75 5	24 5	—	72 9	27 1	—
1919	76 9	23 1	—	78 5	21 5	—

looms and the rapid development of the worsted weaving industry are clearly noted in this table The reason for the change to wider looms is to be sought in part in market conditions as well as in technical development Narrow goods served the custom tailor and domestic seamstress well enough, but the advent of large-scale operations of wholesale clothiers and the use of electric cutters led to a demand for wider piece goods After 1880 worsted coatings were demanded in wider bolts and this brought about a rapid shift in the worsted branch which became significant about 1899

More recently two further innovations aided this trend The introduction of direct loom drives and the application of automatic filling changing apparatus to woolen and worsted looms played a very important part in this period The former was the result of the increased use of electricity and was first recorded in the Federal census of 1899 It became of real importance about 1919 It meant a motor to each loom, greater flexibility and effectiveness in weaving, a great impetus toward real mass production, and more perfect goods Even greater in importance was the distinctly American in-

vention of the filling changing loom It was adopted for wool about 1905 following its introduction in the cotton industry, which occurred about 1894 The original Northrop loom had only one shuttle in operation, whereas the automatic Crompton & Knowles loom adapted for wool kept four shuttles active, which permitted "mixing of weft" and the use of more than one color, important aids in woolen goods manufacture However, its adoption was not as rapid as in the cotton industry and it was not until after World War I that any real progress was made

THE RECENT PERIOD—1919-1946

BY GLEN F. BROWN

Statistician, National Association of Wool Manufacturers

At the beginning of November 1918 the industries of the United States were mobilized for vigorous prosecution of the war between the Allied Powers and the Central Powers Between two thirds and three quarters of the entire facilities of the woolen and worsted industries were operating on cloths, blankets, and other materials for the federal government and the government owned practically the entire supply of wool available for manufacture.

The signing of an armistice on November 11, 1918, brought hostilities abruptly to an end, and the whole world began immediately to look forward to the return of living in peace For the woolen and worsted industries this meant a change-over from operations to fulfill government requirements to operations to satisfy the needs of the civilian population It meant far more than a return to conditions existing before the war The war was more than a mere interlude It had set into action powerful and far-reaching forces, many of which were to be permanent in their effect on the economic machines of the United States and the world

Wool and Mohair Production

Following a heavy clip in 1919 the amount of wool shorn annually in the United States through 1925 varied between 228,000,000 and 253,000,000 pounds During the next four years production expanded and after 1929 the clip stabilized at a much higher level, fluctuating between 350,000,000 and 375,000,000 pounds through 1940. Under war stimuli it almost reached 390,000,000 pounds in

1941 and 1942, but changing price relations and lack of help caused it to shrink sharply after 1943 The clip of 1946 is established at only 280,000,000 pounds These estimates, issued by the U. S Department of Agriculture, are based on the weight of the wool as shorn from the sheep, which is referred to as the "grease weight", and includes a large amount of foreign matter such as grease, sand, dirt, etc However, the wool must be cleansed of this foreign matter before it can be manufactured, and in this process, wools grown in the United States lose, on an average, about 60 per cent of their shorn weight The cleansed wool is referred to as scoured wool

Some wool is grown in every state of the United States but the ten largest producing states, all located west of the Mississippi River except for Ohio, accounted for roughly 70 per cent of the total wool shorn each year Production in Texas increased about fivefold during the period, making that state by far the largest wool-producing state and increasing its proportion of the total clip from about 5 per cent in 1919 to almost 25 per cent in 1945

In addition to the growth in the amount of wool shorn, increasing quantities of wool were also pulled from the pelts of slaughtered sheep During the last seventeen years of the period in the neighborhood of 65,000,000 pounds were pulled each year This was more than 20,000,000 pounds higher than the production during the early 1920s These weights refer to the wool in the condition after pulling In converting this pulled wool to scoured wool a shrinkage of about 30 per cent in weight takes place

The production of mohair in the United States increased two and one half times during the period, reaching 20,000,000 pounds per year, grease weight, beginning with 1940 Mohair (from the Angora goat) is grown commercially in seven states, but 80 per cent of the production came from Texas during the earlier years of the period and about 90 per cent during the latter years.

Wool Prices

Wide and sometimes violent fluctuations occurred in apparel class wool prices during the period These effects are dampened in the accompanying chart (Fig 5) based on annual averages, but are nevertheless apparent The highest prices were actually reached in February and March of 1920 during the inflationary period following World War I, when territory staple fine and

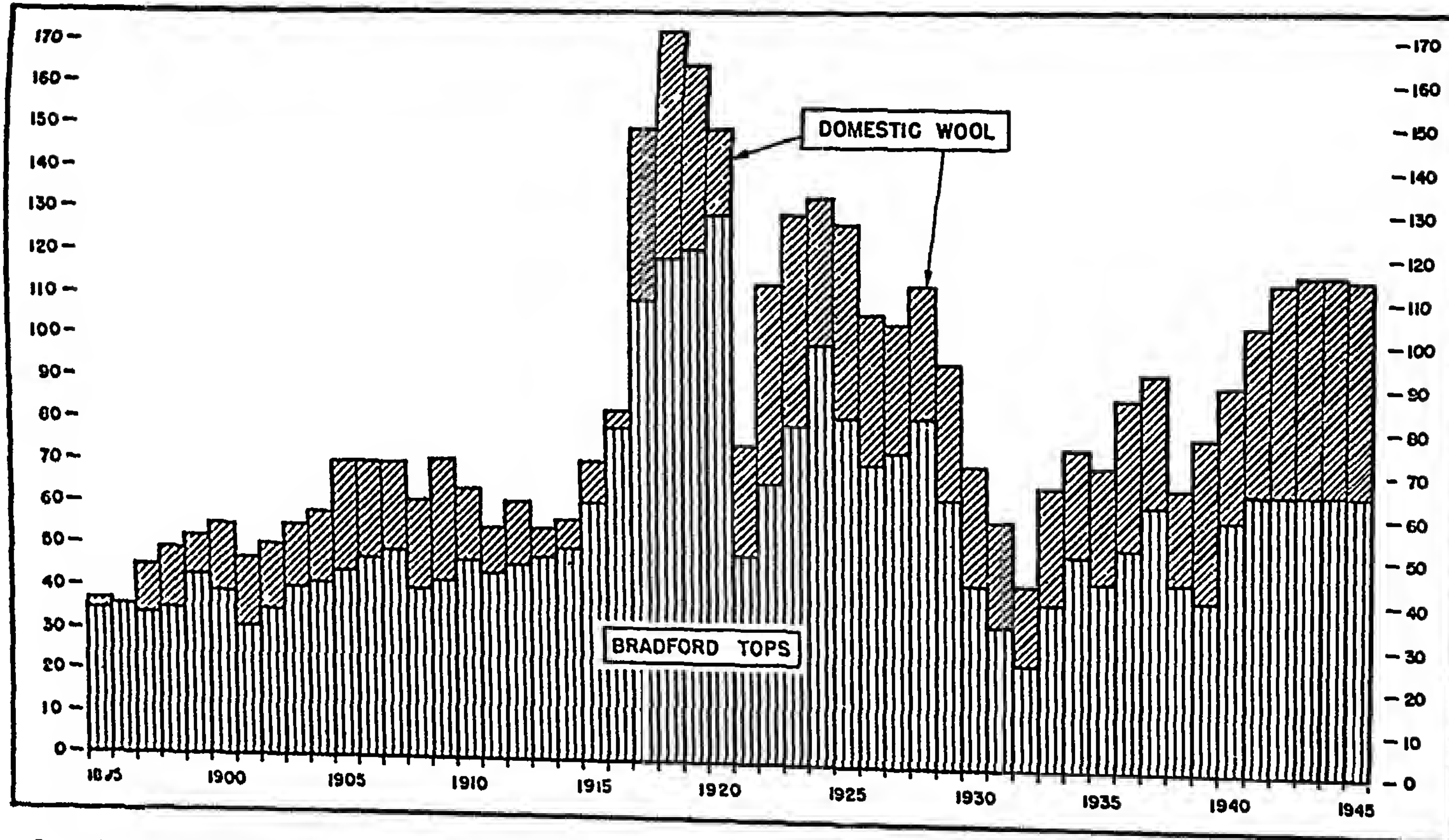


Fig 5 Fluctuations in wool prices as shown by combined yearly averages of top prices in Bradford, England and combined yearly averages of domestic wool prices (scoured basis) in Boston (in cents per pound)

fine-medium wools sold on the Boston market for $2 05 per pound scoured basis The lowest prices prevailed in June and July of 1932, when the same wools sold for 38 cents per pound.

Prior to World War II, except for relatively short periods of time, world prices were the determining factor on prices in the United States, since it was necessary throughout the period to import wool to meet the total demand Government wartime controls influenced prices during the last years of the period World prices ere largely established through controls of the British Empire while ying policies of the armed services principally determined the price of wools grown in the United States Domestic wools were priced out of the market by measures to encourage their growth and restricted their use to military fabrics When military procurement failed to absorb all domestic wools, they were taken over by the Commodity Credit Corporation At the close of the period this government agency owned 448,000,000 pounds of wool

In Australia, New Zealand and South Africa the sale of wool at public auction was resumed in the fall of 1946 with prices supported at minimum levels by a Joint Organization formed for orderly liquidation of their war-time accumulation of wools

Almost steadily through the period into the early 1940s the price of wool increased in relation to the prices of other principal textile materials The price relation between wool and rayon was completely reversed During the early years of the period a specified rayon cost almost three times as much as wool, while by the close of the period it sold for less than half the price of wool After 1941 silk ceased to be a market factor due to the war, and cotton returned to the same price relation to wool as prevailed during the early years of the period.

The Tariff on Raw Wool

During this period there were several outstanding developments concerning the tariff on raw wool Under the Tariff Act of 1922 the duty for the first time applied against the clean content of the wool, namely, the wool free of all foreign matter such as grease, sand, dirt, and vegetable matter, and in a normal condition as to moisture In all previous tariff acts which levied a duty on raw wool the rate had applied against the actual weight of the wool as imported The second development evolved in the Tariff Act of 1930 In previous acts certain wools, which were designated as

Class III or carpet wools, were permitted free entry, if used in carpets or rugs In the Act of 1930 this category of wools was widened to include all wools not finer than 40s grade, and uses permitted without payment of duty were extended to include press cloth, knit or felt boots, and heavy fulled lumbermen's socks, in addition to carpets, rugs, or other floor coverings

Under the Reciprocal Trade Agreements program, agreements with Argentina (1941) and Uruguay (1943) reduced the duty 11 cents per pound on clean content for wools not finer than 40s and other specified wools commonly called carpet wools, and 12 cents per pound on clean content for wools not specially provided for, and grading finer than 40s but not finer than 44s Agreements with Peru (1942) and Iran (1944) also reduced the duty on hair of the alpaca, llama, cashmere goat, and vicuña 16 cents per pound on clean content All of these changes involved reductions in the duty of between 40 and 50 per cent. The present duties on wools imported into the United States are shown in Chapter 25

Wool Consumption at the Mills

With only negligible exceptions all of the wools grown in the United States are manufactured at mills within the United States In addition, it is necessary to import all of the carpet and rug wools (which are not grown in this country), and to augment the domestic wool production by importation of similar wools from abroad By and large, imports of this latter class of wools fluctuate with the spread between consumption and domestic production They amounted to about 45 per cent of the total mill consumption of apparel class wools from 1919 through 1926, about 30 per cent from 1927 through 1930, about 10 per cent from 1931 through 1935; and about 25 per cent from 1936 through 1939 Beyond 1939 the percentage was much larger, being influenced not only by the large consumption arising from wartime demands, but also by stock-piling activity arising from the same influences.

A representative average annual consumption of shorn and pulled wools at all kinds of mills in the United States for various periods is shown in Table 5 Carpet class wools consist of those wools of the sheep particularly suitable for, and chiefly used in, carpets and rugs, although sometimes used in other products Their consumption after 1941 was influenced heavily by wartime conditions which restricted their availability and resulted in conversion of carpet manufacturing facilities to other products Apparel class

TABLE 5 CONSUMPTION OF SHORN AND PULLED WOOLS IN MILLS IN THE UNITED STATES

(In millions of pounds—scoured basis)

Apparel Class	*Carpet Class*
Av 1919–23—294	Av 1919–21— 47
1924–29—250	1922–29— 99
1930–34—208	1930–34— 62
1935–40—286	1935–41—102
1941–45—568	1942–45— 44
1946- —620	1946- —128

Source Computed from reports of the Bureau of the Census

wools include all other wools of the sheep, and, while largely used in apparel of one sort or another, find use in numerous other items such as blankets, upholstery, draperies, carpets and rugs, felts, and industrial fabrics For the purpose of Table 5, the wool was considered consumed when it passed one of the earlier stages in the manufacturing processes The figures in the table do not represent the amount of wool reaching consumers in the United States each year because they omit, among other things, imported wool wastes and by-products introduced into manufacture in this country at stages beyond that of the measurement, imported manufactured items containing wool, and wool recovered from items discarded by consumers and reutilized

It is probable that between 85 and 95 per cent of the shorn and pulled wool consumed was spun into yarns on the woolen and the worsted spinning systems The balance of the wool consumed went, in the main, into felts or was spun in mixture with other fibers on the cotton and silk spinning systems

Materials Spun on Woolen and Worsted Systems

No statistics on the kinds and amounts of fibers spun into yarns on the worsted systems in the United States are available prior to 1937, but it is estimated that throughout the period roughly 90 per cent of the total fibers handled consisted of shorn and pulled wool of the sheep, the balance being largely mohair but also including cotton and other animal fibers such as camel's hair, alpaca and cashmere During 1935 and 1936 the spinning of top made from rayon staple fiber and rayon waste in mixture with wool and other fibers became prevalent, and in 1937 constituted about 5 per cent of the total fiber consumption on the worsted systems It probably never exceeded this proportion of the total consumption during the

balance of the period, although the actual poundage consumed was greater in 1943 when conservation restrictions on the use of wool limited its availability for civilian manufacture and the use of rayon was encouraged by the government as a means of extending the supply of materials for civilian use.

Statistics on the kinds and amounts of fibers spun into yarns on the woolen system are of even more recent origin and, with the data at hand, any guess is much more hazardous than in the case of the worsted system It appears that during this period roughly 80 to 90 per cent of the total fibers spun on the woolen system were shorn and pulled wool of the sheep, or wool wastes and wool by-products, or wool or part-wool recovered fiber Prior to 1942 probably more than one half of this total were wastes, by-products, and fiber recovered from rags and clips, but from 1942 on the proportion may have been somewhat smaller owing to the restricted supply and the large quantity of blankets (requiring shorn and pulled wool) made for the armed services A number of fibers made up the remaining raw materials but in volume cotton pre-dominated, although the use of rayon wastes and staple fiber increased considerably during the last ten years of the period

Number of Woolen Spindles

The number of woolen-system spinning spindles in place in all kinds of mills in the United States declined about one third during the period to 1,600,000 spindles at its close (See Table 6) Most of this loss came after 1929 Mule spinning dominated the field, although frame spinning increased to about 15 per cent of the spindles in place at the close of the period

TABLE 6

WOOLEN SPINNING SPINDLES IN PLACE IN UNITED STATES
(In thousands)

Date	*Number*
Dec 1919	2,401
1925	2,460
1930	2,265
1935	1,916
1940	1,684
1946	1,600

Source Bureau of the Census

The proportion of the spindles in the New England and Middle Atlantic states declined some during the period as the number of

spindles in the Southern states increased, despite the sharp reduction in the total number. Nevertheless, at the close of the period over three quarters of the total spindles in place were located in the New England and Middle Atlantic states The states of Massachusetts, Pennsylvania, and Connecticut were the largest losers both in number of spindles and in the ratio of loss to the number of spindles in each state

Number of Worsted Combs

The number of worsted combs in place in the United States increased through the middle of the 1920s and then started a steady decline which continued until toward the close of the period, when the trend was reversed under the stimulus of the insistent war demand for top In contrast to other types of machinery, there were more combs in place at the close than at the beginning of the period.

TABLE 7

WORSTED COMBS IN PLACE IN UNITED STATES

Date	*Bradford*	*French*	*Total*
Dec 1919	—	—	2,382
1925	—	—	2,787
1930	—	—	2,712
1935	1,880	751	2,631
1940	1,675	815	2,490
1946	1,651	950	2,601

Source Bureau of the Census

Over 95 per cent of the combs were located in the New England and Middle Atlantic states throughout the period. The concentration of combs in Massachusetts and Rhode Island increased largely at the expense of New York and Pennsylvania

Number of Worsted Spindles

The number of worsted-system spinning spindles in place in all kinds of mills in the United States increased, as did the number of worsted combs, through the middle of the 1920s and then started a steady decline to the end of the period At the close of the period there were almost 25 per cent fewer Bradford system spindles in place than at the beginning of the period, and about 10 per cent fewer French system spindles (See Table 8)

TABLE 8

WORSTED SPINNING SPINDLES IN PLACE IN UNITED STATES
(In thousands)

Date	*Bradford*	*French*	*Total*
Dec 1919	1,646	710	2,356
1925	1,877	880	2,757
1930	1,690	820	2,510
1935	1,515	750	2,265
1940	1,379	657	2,036
1946	1,272	644	1,917

Source Bureau of the Census

Throughout the period over 90 per cent of the total spindles in place were located in the New England and Middle Atlantic states, but there were some shifts in the distribution among the states in these groups A comparison of the spindles in place at the beginning and close of the period in the principal states shows the largest percentage declines in Pennsylvania and New Jersey, the greatest loss of spindles in Massachusetts, and some gain in Rhode Island and in other New England states combined

Ring spinning increased during the period in both the Bradford and the French systems of spinning, but at the close of the period cap spinning still dominated in the Bradford system, accounting for about 75 per cent of the total spindles in place Mule spinning dominated in the French system, accounting for about 80 per cent of the total spindles in place

Number of Woolen and Worsted Looms

There also was some increase through the middle of the 1920s in the number of broad looms (50 inches or more reed space) in place in the United States weaving materials (other than carpets and rugs) primarily from yarns spun on the woolen and worsted systems But from the middle twenties to the end of the period the number in place declined to about 40 per cent less than at the beginning The use of narrow looms in weaving such materials declined steadily throughout the period and by its close, they were practically nonexistent Narrow looms were discarded because of the growing preference for wider cloths and a drying up of narrow cloth markets.

During this period looms with automatic filling change came to a predominating position At the close of the period about three quarters of the broad looms in place were looms of this type. While the total number of broad looms in place declined about 17,000 between 1930 and 1946 the number of broad looms with automatic filling change actually increased about 8,000 looms Some of these automatic looms are of a type readily convertible to regular 4-by-4 nonautomatic box looms

TABLE 9

WOOL MACHINERY IN PLACE IN PRINCIPAL STATES AND AREAS OF THE UNITED STATES—DECEMBER 27, 1941

States and Areas	*Woolen and Worsted Looms*		*Spinning Spindles*		*Worsted Combs*
	Broad[4]	*Narrow*[5]	*Woolen*	*Worsted*	
United States	38,979	2,440	1,634,668	1,955,512	2,494
New England	25,053	1,453	876,691	1,397,542	1,714
Connecticut	2,302	341 (a)	143,766	14,680	(a)
Maine	3,559		157,018	101,512	(a)
Massachusetts	10,319	728	335,408	704,212	1,082
New Hampshire	2,842	74	121,124	55,860	(a)
Rhode Island	5,165	258	77,516	500,942	555
Vermont	866	52	41,859	20,336	N
Middle Atlantic	7,914	677	403,602	465,886	678
New Jersey	2,567	60 (a)	66,917	156,866	398
New York	1,968		196,767	88,632	73
Pennsylvania	3,379	617	139,918	220,388	207
Southern[1]	2,878	310 (a)	159,112	40,448	102 (a)
North Central[2]	2,616		166,571	40,856	
Western[3]	518	N	28,692	10,780	

[1] Alabama, Delaware, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Texas, Virginia, and West Virginia
[2] Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio and Wisconsin
[3] California, Oregon, Utah, Washington, and Wyoming
[4] Over fifty inches N. None
[5] Fifty inches and under
(a) Cannot be shown separately without disclosing the equipment of individual mills
Source. Bureau of the Census

TABLE 10

WOOLEN AND WORSTED LOOMS IN PLACE IN UNITED STATES

Date	Broad Looms	Narrow Looms
Dec 1919	62,7[illegible]	18,981
1925	64,1[illegible]	18,121
1930	54 [illegible]07	12,852
1935	41,[illegible]0	7,769
1940	41,4[illegible]0	4,683
194[illegible]	37,369	1,776

Source Bureau of the Census.

At the close of the period about 80 per cent of the broad looms were located in the New England and Middle Atlantic states, although the number of looms in the Southern states had increased All the New England and Middle Atlantic states shared in the liquidation during the period, but it appears that Massachusetts lost not only the greatest number of looms, but also shared with Pennsylvania and New Jersey in loss of the largest proportion of their looms.

Wages, the Work Week, and Labor

Wages The peak of the rise in the wages of woolen and worsted mill employees that was induced by World War I was reached in 1920 Between 1920 and the start of the rise associated with World War II there were several major adjustments in wage scales As the country went into the depression of 1921 a large number of mills effected cuts of 22½ per cent Wage rates dropped again,

TABLE 11

AVERAGE HOURLY EARNINGS OF FACTORY EMPLOYEES IN WOOLEN AND WORSTED GOODS MANUFACTURE

Period	Earnings	Period	Earnings
1920	63	Dec. 1941	70
1922–1930	47– 53	1942	79
1932	39	1943	82
May 1933	28	1944	85
Dec 1933	48	1945	90
1934–1936	.48– 50	1946	1 04
1937–1940	.53– 59		

Source U. S Bureau of Labor Statistics

as the country sank deeper and deeper in the depression of 1932 The low point was reached in the first half of 1933. On August 15, 1933, the Code for the wool textile industry under the National Industrial Recovery Act became effective, and average hourly earnings jumped abruptly from the neighborhood of 30 cents to 48 cents. A series of changes during the period from December 1936 through 1940 resulted in average earnings between 53 cents and 59 cents In early 1941 a rise in wages started that was still in progress at the end of the period, when earnings averaged $1 04 per hour

The work week The length of the full-time work week of employees was shortened twice during the period. In 1919 the forty-eight-hour week replaced the fifty-four-hour week as the usual schedule for a large number of employees, although in some areas operations continued on a fifty-four-hour basis The forty-hour week was adopted under the code in August 1933 and applied to all mills subject to the code This schedule continued as the usual work week, even after the invalidation of the N I R A code structure through a Supreme Court decision early in 1935

Labor During the period three major labor disturbances took place In early 1919, in making demands for a forty-eight-hour week, it was not clear for a time whether it was expected that the hourly rate of pay should remain the same or whether an adjustment would be asked so that the pay for forty-eight hours should equal the amount then paid for fifty-four hours In many instances the forty-eight-hour week was granted without any hourly wage adjustment, but labor difficulties arose in Lawrence, Mass , Passaic, N J , and Woonsocket, R I In the Woonsocket area adjustments were quickly effected and in Lawrence hands began drifting back to work from the outset of the difficulties; however, in Passaic two months passed before the mills were reopened

On January 25, 1926, a strike broke out in the Botany Worsted Mills at Passaic, N J , which quickly spread to the other woolen mills in the area and even to other types of mills More than a year elapsed before some of the mills got back into operation after labor difficulties that were stated by some textile people to have surpassed those of the Lawrence strike of 1912

In early September of 1934, as a part of a general textile strike voted by the United Textile Workers, a large number of woolen and worsted mills were closed On September 5 President Roosevelt issued an Executive Order authorizing the setting up of a board, which later became known as the Winant Board, to inquire into

complaints of the workers and the problems confronting the employers On September 17 the Winant Board recommended to the President the creation of a Textile Labor Relations Board and a series of studies in connection with problems raised On the basis of these recommendations the union announced the termination of the strike, and on the following Monday the mills reopened

The organization of employees by unions progressed steadily after the formation of the Committee for Industrial Organization in the middle 1930s, and at the end of the period the employees of a substantial number of the mills in the industry were covered by contracts with unions Most of these contracts were with the Textile Workers Union, affiliated with the C I O, the United Textile Workers, affiliated with the A F L, and the Industrial Trades Union, an independent group in Rhode Island

Full-Time Operating Schedules

A significant transition took place during the period in the full-time operating schedules of plants and machinery Reference has already been made to two shortenings in the length of the work week In addition, multiple-shift operation was supplanting single-shift operation This trend was accelerated in 1933 by the N R A code for the wool textile industry which not only shortened the length of shifts to forty hours per week but also, through its wage provisions, raised labor costs. There was a distinct trend toward

TABLE 12 PERCENTAGE OF ACTIVE MACHINES OPERATING TWO OR MORE SHIFTS

Period	*Broad Looms*	*Woolen Spindles*	*Worsted Spindles*	*Worsted Combs*
1921	4	7	6	24
1925	7	13	9	25
1930	19	14	15	31
1935	71	57	47	69
1940	78	58	56	72
1942	86	73	64	85
1945	74	62	45	74
1946	79	70	53	82

Source Derived from reports of the Bureau of the Census

three-shift operation after the middle 1930s This trend reached a peak in 1942 when the following percentages of the active machines were running three shifts. broad looms, 31 per cent, woolen spindles,

34 per cent; worsted spindles, 12 per cent; and worsted combs, 57 per cent Both two-shift and three-shift operation receded some after 1942 owing to the shortage of help

Woven Cloth Markets

Of the cloths woven during 1919-1946 containing by weight 25 per cent or more of yarns spun on the woolen and worsted systems over four-fifths were for use in wearing apparel of one sort or another The large part of the balance was for use as blankets, draperies, and upholstery The most significant development during the period in connection with nonapparel cloths was the development and growth of the "closed" automobile with its upholstery requirements

With so large a part of the market in wearing apparel, forceful repercussions from the happenings in these fields were inevitable Factory-made wearing apparel for women continued to grow in favor and largely displaced home and local dressmaking Fashion and other factors such as the use of closed automobiles and central heating dictated both fewer and lighter clothes These eliminated some markets and wool manufacturers experienced difficulty in adjusting their product to the remaining markets Furthermore, women in greater numbers could afford the luxury of fur coats In men's clothing the most significant development was the recognition and increase in use of specialized clothing for summer wear These included not only lightweight clothing of conventional design, but also slack suits and slacks with a variety of upper garments, all with requirements more adaptable to non-wool cloths. At the same time, progress in finishes was imparting to cloths of other fibers some of the characteristics inherent in wool

TABLE 13

PRODUCTION OF WOVEN APPAREL CLOTHS IN UNITED STATES BY MILLS PRIMARILY WEAVING CLOTHS WHOLLY OR IN PART OF YARNS SPUN ON THE WOOLEN AND WORSTED SYSTEMS

(In millions of square yards)

Year	*Production*	*Year*	*Production*
1919	510	1937	471
1925	527	1942	685*
1929	416	1946	786

*Includes substantial quantities for the Army and the Navy

Besides, there was increased competitive pressure in all markets from several newcomers. The knitting trades developed or exploited their product in numerous new fields Most significant was their entry into the coating, topcoating, and overcoating markets, and during the later years of the period a substantial portion of the men's and boys' topcoats and overcoats were made from knit cloth Then there was the astounding growth of rayon and other synthetic fiber industries The use of filament rayon yarns in broad woven goods increased from less than 3,000,000 pounds in 1919 to 300,000,000 pounds during the later years of the period, and a large part of these goods were for the dress and lining markets Since 1930 the production of rayon staple has grown from less than 500,000 pounds to 175,000,000 pounds per year This staple fiber is processed largely on cotton system machinery, some in combination with wool, into a large variety of fabrics

World War II Procurement by the Armed Services

The procurement of cloth by the armed services was occasioned largely by their policy of furnishing the component materials for the manufacture of most of their garments, although some cloths were purchased for other reasons such as war aid to other nations Procurement for World War II began about the middle of 1940 in connection with steps taken to bolster the defenses of the country, and substantial quantities of wool cloths and blankets were delivered prior to the Japanese attack on December 7, 1941 These quantities are included in Table 14.

TABLE 14
DELIVERIES OF PRINCIPAL WOVEN CLOTHS AND BLANKETS TO THE ARMED SERVICES FOR WORLD WAR II

Service	*Worsted Cloths**	*Woolen Cloths**	*All-wool Blankets†*
Army	334	198	60
Marine Corps	6	16	2
Navy (exc Marines)	4	77	14
Total	344	291	76

*Wholly or in part of wool in millions of linear yards
†In millions of blankets largely 66 by 84 inches

Source 1945 Bulletin, National Association of Wool Manufacturers.

The peak period of deliveries of worsted cloths was the second half of 1942, but on woolen cloths and blankets the peak was not reached until the first half of 1943, when large deliveries of blankets were made to the Army for its Medical Corps, and Navy and Marine requirements reached their crest. Deliveries then tapered off through 1944, but reached a secondary peak in the first half of 1945, when it appeared it might be necessary to provide for winter campaigns in temperate zones on two fronts The effective capacity to produce had been considerably lessened by this time and facilities were taxed to a greater extent than in the last half of 1942 All worsted production facilities were frozen against priority rated orders, and while it was not deemed practical to freeze woolen facilities, the War Production Board issued directives to each individual mill based on the manufacturing potentiality of its equipment.

Worsted Yarn and Wool-Top Markets

Since the knitting trades in the United States buy practically all their worsted spun yarns they become one of the markets for the wool textile industry A representative average annual production of knitting yarns on the worsted systems for various periods is shown in Table 15.

TABLE 15

KNITTING YARNS SPUN ON THE WORSTED SYSTEMS

(In millions of pounds)

Period	*Bradford System*	*French System*	*Total*
Av. 1920–24	31	9	40
1925–29	27	11	38
1930–34	28	13	41
1935–39	33	10	43
1940–44	47*	10*	57*

*Includes yarn for Army and Navy garments.

During the last ten years of the period a sizeable market for wool top developed among the cotton system spinners for spinning in blends with rayon staple or rayon staple and cotton In addition, during World War II there was a persistent demand from cotton system spinners for wool top to be spun in combination with cotton for Army underwear and Army and Navy socks.

World War II Government Controls

The strategic position of wool in the war potential of the country was early recognized In October 1940 the National Defense Advisory Commission announced that arrangements had been made for the accumulation of a reserve of 250,000,000 pounds (grease weight) of British-owned Australian wool to be stored in bond in the United States These arrangements provided that wool would move to this country from Australia to the full extent of available shipping, but facilities permitted the movement of less than 175,000,000 pounds (grease weight) by December 1, 1941

When war came on December 7, 1941, supply lines over all the seas of the world were threatened To ensure a continuous supply of wool for military needs the War Production Board considered it necessary to limit the over-all mill consumption of shorn and pulled wools and to curtail severely their flow into civilian uses, and to accomplish this end issued on January 3, 1942, Order M-73 Even after the supply situation eased later, this order, amended from time to time, was continued as a vehicle for allotting facilities to priority rated orders In 1945 the War Production Board deemed it necessary to exercise some control over the wool cloths flowing to the civilian markets, and issued Order M-388C, which was later replaced by Order M-328B, Schedule K

The day following the declaration of war the Office of Price Administration announced that ceiling prices would be established for wool at approximately the existing levels, and on December 17 issued Price Schedule 58 setting ceiling prices for wools, tops, noils, and yarns A press release was made at the same time announcing an intention to freeze wool cloth and blanket prices To meet the requirements of the Emergency Price Control Act, which became law in late January 1942, a separate price schedule for shorn wools of domestic growth was issued in late February as Maximum Price Regulation 106 In April came Maximum Price Regulation 123 covering wool waste materials and a General Maximum Price Regulation applying to all products not already covered by specific schedules Most cloths were placed under separate schedules in June 1942 with the issuance of Maximum Price Regulation 157 covering sales to military agencies, and Maximum Price Regulation 163

covering other sales of apparel cloths. Price control on cloth was carried beyond ceiling prices in May 1945 when the Office of Price Administration issued Supplementary Order 113 embodying its Maximum Average Price program (referred to as MAP)

Government procurement of wool of domestic growth through the Commodity Credit Corporation, beginning in 1943, has been mentioned in the preceding section on wool prices

This outline covers the principal controls more or less specifically applying to wool and wool manufacture but omits a host of controls and regulations that affected operations The wage structure was subject to the regulations of the War Labor Board, some products were subject to other price regulations and rules; and prohibitions and controls applied to imports of wool, the use of Olive Drab wastes, bags, packing cases, dyestuffs, lubricants, repair parts, and other items

Foreign Competition

A large quantity of wool top was imported in 1921, and sizeable poundages of yarns came into the country during the early 1920s, but thereafter the imports on these items were much smaller The largest importation of cloths in the period was made during the 1920s and of blankets during the late 1920s and in 1936 and 1937 The United Kingdom was the principal source of imports, although in the fall of 1935 a threat of competition from Japan appeared as manufacturers from that country started a drive to expand markets in this country for yarn and cloth Quality problems impeded progress until the war killed off this threat

Throughout the period foreign competition was held within limits After 1929 world conditions were more important than the tariff in regulating imports, and no adequate test was made of the duties under the Tariff Act of 1930 to meet the new alignments of world currencies and labor costs that evolved during the world depression of 1932, let alone the reduced duties introduced through trade agreements under the Reciprocal Trade Agreements program since 1934 Reductions in the duties on tops, yarns, cloths, and blankets under this program are indicated in Table 16 The duties on wool manufactures will be included among those to be considered for further reduction at a trade conference scheduled for April 1, 1947.

TABLE 16

REDUCTIONS IN IMPORT DUTIES RESULTING FROM RECIPROCAL TRADE AGREEMENTS

Item	*From*	*To*	*Effective Date*
Top	37c per lb +20% ad val.	37c per lb +12½% ad val	Jan 1, 1939
Yarn—rabbit hair	40c per lb +35, 45, or 50% ad val	40c per lb +25% ad val	June 15, 1936
Yarn—other	40c per lb +35, 45, or 50% ad val	30 to 40c per lb +30% ad val	Jan 1, 1939
Woven cloths not over 4 oz per sq yd			
With cotton warp	40c per lb +50, 55, or 60% ad val	40c per lb +37½% ad val	Jan 1, 1939
Without cotton warp	50c per lb +50, 55, or 60% ad val	50c per lb +37½% ad val	Jan 1, 1939
Woven cloths over 4 oz	50c per lb +50, 55, or 60% ad val	40 or 50c per lb +45, 40, or 35% ad val	Jan 1, 1939
Blankets, hand-woven	30, 33, or 40c per lb +36, 37½, or 40% ad val	20c per lb +20% ad val	Jan 30, 1943
Blankets, other	30, 33, or 40c per lb +36, 37½, or 40% ad val	30, 33, or 40c per lb +36% ad val	Jan 1, 1939

Labeling of Wool Products

Agitation continued for both federal and state legislation to require labeling of wool and part-wool fabrics Some of the proposals applied only to wool and part-wool fabrics and garments, but others were more general, applying to all textiles The rapid growth in the use of rayon, both alone and in combination with other fibers, gave impetus to the movement for fiber identification, and removed some of the emphasis, particularly by wool-growing interests, for differentiation between so-called virgin wool and recovered wool fiber.

Several voluntary moves were made to solve the labeling problem. Commercial standards were promulgated by the National Bureau of Standards for wool and part-wool blankets at the close of 1932, for mohair pile upholstery fabrics on July 8, 1935, and for wool and part-wool fabrics on November 20, 1937 One purpose of these standards is to provide standard methods for describing and labeling the products to which they apply On February 5, 1935, the Board of Directors of the National Association of Wool Manufacturers approved a set of regulations for the labeling of fabrics containing camel's hair and other specialty fibers

Nevertheless, agitation for legislation continued and, finally, with the active support of a few manufacturers, culminated in the approval on October 14, 1940, of the Wool Products Labeling Act of 1939 (See Chapter 25) This act requires the labeling of all products containing, purporting to contain, or in any way represented as containing wool, reprocessed wool, or reused wool It is required that the label show the percentage of the total fiber weight represented by each kind of wool and also the percentage of other fibers present, if any

Wool is defined to mean the fiber from the fleece of the sheep or lamb or hair of the Angora or Cashmere goat (and may include the specialty animal fibers from the hair of the camel, alpaca, llama, and vicuña) which has never been reclaimed from any woven or felted wool product

Reprocessed wool is defined to mean the fiber resulting when wool has been woven or felted into a wool product which, without ever having been utilized in any way by the ultimate consumer, subsequently has been made into a fibrous state

Reused wool is defined to mean the fiber resulting when wool or reprocessed wool has been spun, woven, knitted, or felted into a wool product which, after having been used in any way by the ultimate consumer, subsequently has been made into a fibrous state

The recognition of three kinds of wool under the act led almost all manufacturers to oppose its passage This opposition was based on the ground that the evidence failed to indicate a need for such a distinction, that enforcement would be difficult with no known commercial tests that could identify the different classes of wool, and that the proposed differentiation would confuse and mislead rather than inform the public

Wool Promotion and Industrial Co-operation

Wool promotion After 1923 operations generally were not satisfactory and profitable, and in June 1925 an informal conference of representatives of the National Association of Worsted and Woolen Spinners, the American Association of Woolen and Worsted Manufacturers, and the National Association of Wool Manufacturers was held in New York to discuss the unsatisfactory condition of the industry At this meeting the suggestion was made that there was a great opportunity to educate the public concerning wool, its manufacture, and the fabrics made from it In early 1926 it was proposed that the National Association of Wool Manufacturers, the National Association of Worsted and Woolen Spinners, the American Association of Woolen and Worsted Manufacturers, the Philadelphia Wool and Textile Association, and the Boston Wool Trade Association appoint a committee to make a study of the situation and report on the advisability of undertaking a national publicity campaign to promote the greater use of wool and its products The committee organized on May 11, 1926, becoming known as the Publicity Committee of the Wool, Woolen, and Worsted Trades, and four booklets were prepared and issued under its direction Three meetings of the trade planned by the Committee were held in July at Boston, Philadelphia, and New York, and, as a result, the committee requested the respective organizations that had appointed the committee members to select two delegates to a proposed Wool Council of America which was to establish a more permanent form of organization These delegates were appointed and started work but, owing to the disinclination on the part of important manufacturers to accept positions on the Board of Directors, it was voted in June 1927 to abandon the effort

The Wool Institute In this same month of June 1927, a conference of woolen and worsted weavers called by A. D Whiteside, President of the National Credit Office, was held at the Roosevelt Hotel in New York Mr Whiteside urged co-operative effort to combat their ills and suggested the immediate appointment of two committees, a Committee on Production and a Committee on Distribution

The immediate tasks of the Committee on Production were outlined as (1) to influence mills to use a common or uniform method of figuring costs, and (2) to urge the establishment of prices to include a profit Those of the Committee on Distribution were (1) to maintain opening prices through the selling season, and (2) to

make an exhaustive investigation of what might be accomplished through advertising The conference acted on Mr. Whiteside's suggestions and appointed the two committees, which set to work. The need for a more permanent and unified form of organization to pursue this work soon became evident, and late in the year Mr Whiteside was asked to head such an organization, by the close of January 1928 the Wool Institute had been born This organization took over and expanded the activities initiated by the Committees on Production and Distribution

In early 1930 the activities of the Wool Institute were investigated by officials of the United States Department of Justice to determine if some were in violation of the antitrust laws As a result on June 27, 1930, a bill in equity was filed in the United States District Court in New York alleging violation of the Sherman Antitrust Act No testimony was taken, and a consent decree was entered simultaneously with the filing of the bill An effort was made to continue the Institute without the activities enjoined by the court, but it was not successful

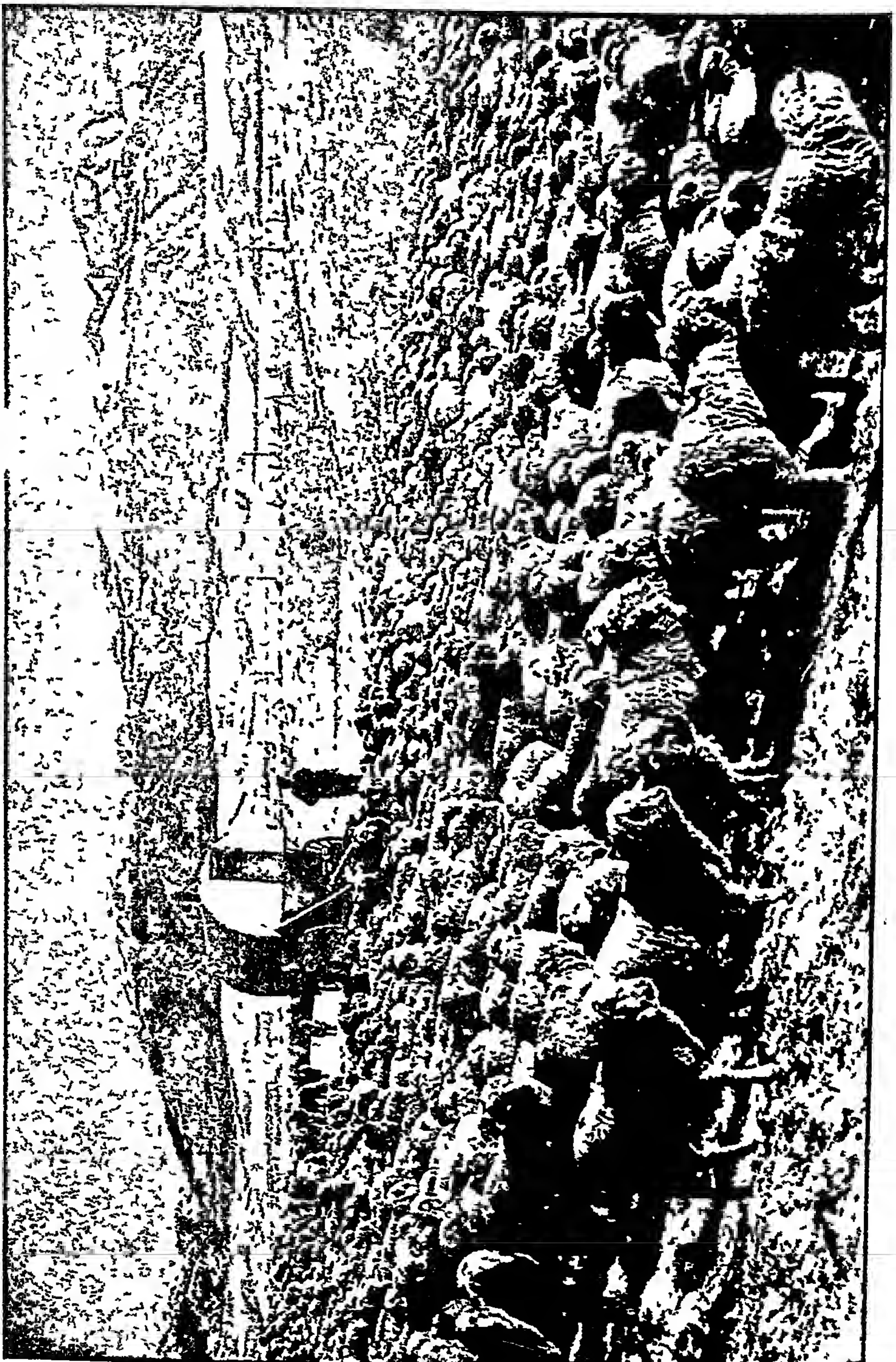
Wool textile industry code (NIRA). On June 16, 1933, the President of the United States signed the National Industrial Recovery Act This Act enabled the President, when certain conditions were met, to approve codes of fair competition for industry and, after approval, the codes had the force of law Such a code was drafted by the National Association of Wool Manufacturers, and submitted to and approved by the President on July 26, 1933. The code for the wool textile industry was the third approved under the law Later, rules of practice and merchandising for various divisions of the industry were submitted and approved The effects of some of the provisions of these codes have already been mentioned On March 25, 1935, the Supreme Court of the United States ruled that the code structure under the National Industrial Recovery Act was unconstitutional

Associated Wool Industries While a formal organization for promoting the use of wool and wool products ceased to exist with the Wool Institute, the idea did not die In February 1935 wool manufacturers, dealers, and growers organized the Associated Wool Industries to promote the use of wool It worked toward its goal through the following activities. (1) informing the public of desirable wool merchandise and its advantages, (2) stimulating the availability of desirable wool merchandise in the wholesale and retail markets, (3) aiding retailers toward more effective and more

profitable selling of wool merchandise; and (4) educating the general public and retail sales clerks about wool, its manufacture, uses, and advantages Financial support of the organization lagged from year to year and, during 1938, the fourth year, its budget was drastically curtailed to about 40 per cent of the first year. In early 1939 an announcement was made that the activities of the organization would be terminated.

International Wool Secretariat In December 1938 the International Wool Secretariat appointed a New York representative This Secretariat, organized about a year previously, has headquarters in London, and is dedicated to increasing the world consumption of wool, being an organization representing the wool-growing countries of the British Empire and supported by a levy on wool exports With the demise of Associated Wool Industries the Secretariat turned its attention toward obtaining the participation of the domestic wool-growing industry in a program of wool promotion.

The National Wool Growers Convention in January 1940 voted to co-operate with the International Wool Secretariat, and approved the mechanics for supporting participation, which entailed the cooperation of the National Wool Trade Association This latter Association agreed to collect and remit the levy approved by the Wool Growers Association when buying wool from growers, providing the growers had signed a contract with a clause authorizing this action A more formal organization of American wool growers emerged for promotional and educational work in March 1941 with the formation of the American Wool Council



Chapter 2

SHEEP BREEDS—SHEEP RAISING

THE sheep is one of man's oldest helpmates and it was probably one of the first animals to be domesticated According to Burns and Moody,[1] very little is known concerning the remote ancestors of the present-day sheep, undoubtedly they are intimately related to the urial and moufflon types of wild sheep

In the beginning sheep were covered only with hair, and wool was merely a soft slight down next to the skin The Scotch blackface sheep is one of the present breeds most closely related to this primitive type

In the earliest pastoral industry one finds that Abraham, the patriarch of the Old Testament, thrived and prospered because of the value of his great flocks and herds According to Crawford, the oldest evidence of wool comes from Asia Minor, from Tell Asmar, the great hill or mound Under a succession of ruined cities were found seals indicating an elaborate system of personal ownership of wool and flocks of sheep There is evidence that trade existed in this venerable fiber The date set for this mound is 4200 B C, or 6000 years ago The pastoral industry was apparently one of the first agricultural pursuits to be established From central Asia, the cradle of civilization, the sheep gradually were introduced into new localities until today they are found over the entire globe Sheep, probably of the fine wool type, had been introduced into Spain by the Phoenicians hundreds of years before the Christian Era There is little doubt that a number of different types of finer "wool" sheep from Asia, Africa, Greece, and Rome were brought into Spain and the various blood lines fused to form the famous Spanish merino sheep, the ancestor of the finest wool-bearing sheep of today

[1] "Trek of the Golden Fleece," *The Journal of Heredity*, Vol 26, 1935

DEVELOPMENT OF BREEDS BY COUNTRY

Spanish Merino Sheep

The development of merino sheep husbandry in Spain is the saga of sheep breeding. Its main development took place between the years 1400 to 1700 A.D. Although sheep breeding and improvement had been known at an earlier date, it did not reach its fullest development until the appearance of the merino in Spain.

In the period from 1500 to 1700 great traveling and stationary flocks of sheep made up the prevailing type of sheep husbandry in Spain. The migratory sheep numbered about 10,000,000 and made up about half of the sheep population of Spain at that time. In contrast to the stationary flocks, which remained in the same district for the entire year, the migratory sheep started north about the middle of April with their lambs, which had been born the previous November. Along the way, they were sheared and the wool prepared for the market in the shortest possible time. The flocks reached the mountain pastures in about six weeks and remained there until the end of September, and then returned to the South. Thus, these hardy sheep traveled twice each year over a trail 400 miles long. Is it any wonder that the Spanish merino and its descendants furnish the foundation upon which our western sheep industry is built? The annual trek of their ancestors is duplicated today in many sections of the American West, where the sheep travel from 100 to 300 miles between their winter and summer ranges. The Spanish sheep industry worked out a system of management for these migratory sheep which was, and still is, a model of efficiency for the conduct of a flock.

The exportation of merino sheep was guarded against with great care. Because no one was allowed to take a live merino out of the kingdom under the penalty of death, it was very difficult to obtain any specimens. As most of the royalty of Europe was related to the Spanish king, it was one of their prerogatives to ask for some of the hoofed bearers of the golden fleece as a gift. Others did not trouble to ask, but smuggled sheep out through Portugal. Through this exportation of the Spanish merino in the second half of the eighteenth century, the foundation of the great wool-raising industry was laid all over the world.

European Merino Sheep

Spain, however, was not the only country with a sheep industry

From the tenth century on, Spain had a rival in England, and by the thirteenth century England was the greatest wool-producing country in the world, although the wool it produced was of a much coarser type By the opening of the nineteenth century, there were about 13,000,000 sheep in England The merino sheep was introduced into England about the year 1791 The climate of the country was not compatible with the requirements of the breed, and, in consequence, the quality of the wool could not be preserved, although much advantage was gained by crossing the merino with native breeds France, Germany, and Austria also produced some wools of fine quality, but only after the introduction of the Spanish merino did the sheep industry in the various countries make considerable headway.

In Germany, the year 1765 marks the date when the Elector of Saxony, a cousin of the King of Spain, was able to obtain a gift of 300 sheep from the Royal Escorial flocks These selected Spanish merinos, under the excellent care of a Saxony shepherd, developed the finest fleeces the world had ever seen up to that time Marie Theresa was responsible for the importation of Spanish merino into Austria-Hungary in 1771 They were established on a government farm in Hungary

France made its debut in the wool-growing business in 1786, when Louis XVI bought a flock of 380 sheep from the King of Spain, which he established on the Rambouillet estate, an experimental government farm These sheep did so well that in 1799 another flock of 237 sheep was obtained During the reign of Napoleon it was said that approximately 20,000 merinos were brought into the country and distributed throughout France In developing the Rambouillet type, the French put special value on the development of the mutton quality The blood of the Rambouillet flock has been kept pure since the first introduction of Spanish merino into France The Rambouillet breed is of special interest to the United States, because it is this breed which since 1893 has spread rapidly throughout the country as the best breeding type.

Another important sheep country is Russia, where the first merino sheep were introduced in 1802 by a Frenchman. They were brought to the southern part of Russia. During recent times a great many American and Australian merinos have been used to improve the Russian flocks.

Australian Merino Sheep[2]

When Australia was first settled, little thought was given to its natural herbage, which most writers described as insufficient to nourish animals in any numbers Not a single sheep was living in Australia up to 1750

Brought to Australia by Governor Phillip from the Cape of Good Hope in 1788, the first sheep were of Bengal or Dutch origin, had hairy fleeces and fat tails, and were designed for food and not for wool production

In 1789 Captain Waterhouse was sent by the authorities to the Cape of Good Hope to obtain sheep He purchased thirty-two Spanish merino sheep there, twenty-nine of which reached Australia safely

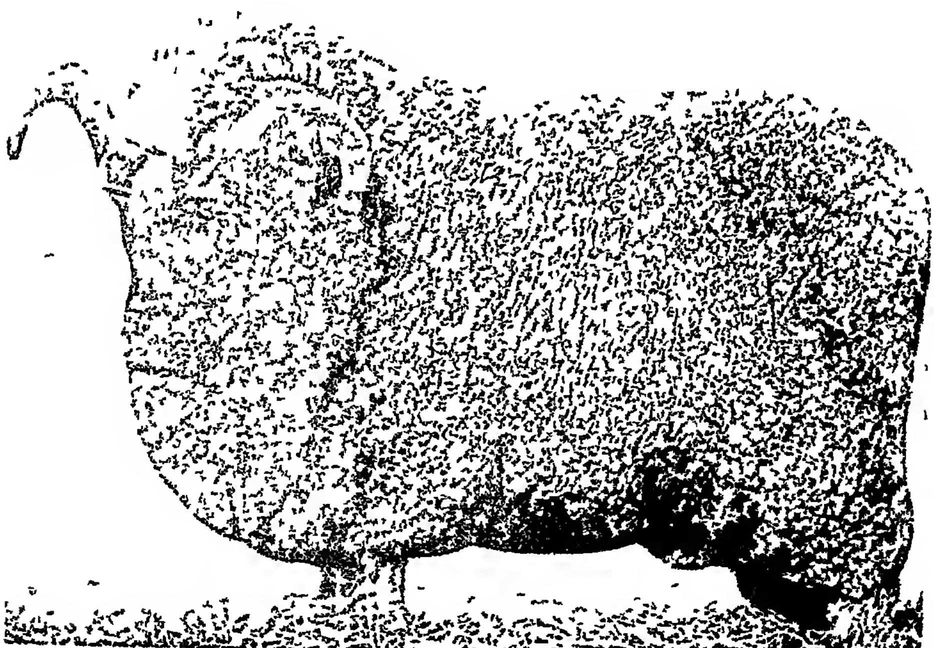


Fig 1 Australian merino ram of New South Wales

Courtesy J. F Wilson, University of California

[2] Official history, from the Australian Wool Council

An army officer, Captain MacArthur, was the first man in the colony to cultivate land Among the original livestock on his farm were a small flock of Indian and Irish sheep to which he added in 1797 two merino rams and four ewes from sheep imported from the Cape Captain MacArthur had earlier realized that "A petty population, established at so vast a distance from other civilized parts of the globe, could have no prospects of ultimately succeeding, unless by raising as an export some raw material which would be produced with little labor, be in considerable demand, and be capable of bearing the expense of the long sea voyage" The commodity which, in his opinion, was most likely to fulfill these requirements was wool Other colonists, too, had realized the possibilities of establishing a fine wool industry, and most notable of these were the Reverend Samuel Marsden and William Cox

Realizing that, if the infant industry were to be developed in earnest, interest must be aroused in London, Captain MacArthur visited England in 1803, taking with him samples of merino wool He succeeded in interesting the wool trade in London, but, more important, he brought back with him five rams and one ewe from King George's own flock of pure Spanish merinos The sheep were to have a profound influence on the development of sheep in Australia

The first commercial export of fine wool from Australia consisted of a consignment in 1807 of 245 pounds · London merchants eagerly sought samples of the new wool and paid high prices for it, one bale realizing as much as £16 4*s* per pound. Year by year increasing quantities of Australian wool were arriving in England, and simultaneously the quality of the product was improving By 1828, England had admitted that the wool from the colony was longer, softer, and more resilient than any but the best German wools and, moreover, was exactly suited to the manufacture of cloths then in demand

The eighteen-thirties marked the rapid extension of the industry in Australia Men spoke and dreamed of nothing but sheep The cry was "put everything in four feet," and by 1840 the flocks had spread irresistibly over large portions of the areas now known as New South Wales, Victoria, Tasmania, and Queensland Australian exports to England increased at an amazing rate from 4,000,000 pounds in 1835 to 13,000,000 pounds in 1842 Wool became the great national industry

In the forties came the greatest crisis in the history of Australia

The rapid growth of the wool industry and the spread of settlement had caused boom conditions which were without real foundations, and in 1841 the bubble was pricked Conditions grew rapidly worse until, by 1843, ruin was widespread At this time too, the world price of wool showed a downward trend, and prices of sheep dropped to ridiculous levels. It is on record that one squatter sold his 9000 sheep at the rate of a shilling a dozen In this crisis the squatters adopted a desperate expedient of "boiling down" and by the end of 1844 nearly 200,000 sheep had been so treated Tallow was worth about 3*d* per pound and the average sheep provided about 12 to 15 pounds of tallow By 1845 however, the colony was once more on the road to progress, and in the next year, with rising wool prices, the flock numbers once again began to increase

In 1850 there were 16,710,566 sheep in Australia The next problem that faced the industry was the acute shortage of labor, caused by the discovery of gold and the rush to the gold fields

While the industry was experiencing all the growing pains which have seemed inevitable in the development of a young country, the flockmasters, by careful selection and breeding, were steadily improving their flocks. In addition to the Spanish merinos they brought famous Rambouillet merinos from France, Nigretti merinos from Germany, and later Vermonts from the United States. The flocks thrived and multiplied in the dry clear atmosphere of Australia's grassy plains.

By 1891 there were 106,000,000 sheep in Australia, but the next decade witnessed a series of dry seasons and in 1902 the country experienced the most devastating drought in its history At this time too, the spread of rabbits, which had become a pest after 1880, became a serious factor. Indeed droughts and rabbits so affected pastoral lands that by 1902 sheep numbers had dropped to 53,000,-000—just half what they had been ten years previously.

These figures proved the lowest of the century and there was a gradual recovery. In the interval between then and now there have been repeated drought periods with consequent severe losses, the season of 1944-45 being an illustration of this point Unfortunately, the position was rendered more serious than usual for two reasons: there was a shortage of labor on the stations and the railway authorities in some states were unable to remove stock from drought areas to more favored districts because of an acute scarcity of trucks brought about by a coal shortage and by prior defense needs.

TABLE 1

COUNT OF AUSTRALIAN SHEEP, 1899–1944

Year	*Number*	*Year*	*Number*
1899	73,061,650	1923	81,035,356
1900	70,602,995	1924	87,669,331
1901	72,040,211	1925	96,343,098
1902	53,669,347	1926	102,960,694
1903	56,932,705	1927	100,743,316
1904	65,823,918	1928	103,307,460
1905	74,403,704	1929	104,455,026
1906	83,687,655	1930	110,366,302
1907	87,887,909	1931	110,597,106
1908	86,896,914	1932	112,906,067
1909	92,241,226	1933	109,891,241
1911	92,742,034	1934	112,146,477
1912	83,451,867	1935	108,863,052
1913	85,096,859	1936	110,154,301
1914	82,011,606	1937	113,043,274
1915	73,672,270	1938	110,477,167
1916	75,594,459	1939	118,817,782
1917	85,309,863	1940	122,655,067
1918	91,747,752	1941	125,562,570
1919	89,076,211	1942	124,175,839
1920	76,823,350	1943	123,029,916
1921	82,921,391	1944	105,068,740
1922	84,691,864		

Source Dalgety's Annual Wool Review, 1944-1945

Table 1 reflects the seasonal vicissitudes to which the wool industry is subject, the decimating effects of disastrous droughts, the remarkable recuperative powers of the industry in favorable times, and a substantial increase in number over the full period of the comparison The point which calls for emphasis is that the increased production and extent of recuperation revealed have resulted principally from the sustained development of the sheep by means of scientific methods While there were influences retarding progress in sheep breeding, such as the diversion of much sheep country to agricultural production by the spread of closer settlement and the cutting-up of large pioneering flocks, there have been equalizing influences, such as improvements in carrying capacity, the tapping of artesian water supplies, and more scientific feeding.

Today, with the growth of other rural undertakings and the development of secondary production, wool is still the basic industry of the Commonwealth It represents 41 per cent of the value of Australia's total exports, and is the largest individual export item Australian sheep, while numbering less than one sixth of the world's

total sheep population, produce one quarter of the world's wool supply and one half of the world's fine merino wools

Of the wool appraised in the Commonwealth during 1944-45 76 per cent consisted of merino wool and 24 per cent of crossbred wool These proportions compare with an average of 84 per cent merino and 16 per cent crossbred for the five years 1935-39. The average wool production for the five years 1940-44 reached a high of 1,112,000,000 pounds, compared with 996,000,000 pounds for the 1935-39 period

South African Merino Sheep

In 1724 the Dutch Government was in possession of the Cape Colony and was the first to import a few merino sheep This undertaking did not meet with much success After the Colonies were ceded to Great Britain the merino received an extensive trial in South Africa In the most favored districts around Port Elizabeth, Durban, and part of the Transvaal, the flocks were established, thrived, and produced a good quality of commercial wool During the years since 1900 some excellent flocks and breeding stocks have been established through importation from Australia, and in wool production South Africa compares favorably with other countries

The sheep total of 1945 was estimated at 38,880,000 compared with an average of 39,900,000 during the years 1936-40 The wool production for the five years 1935-39 amounted to 250,000,000 pounds, or approximately 6 per cent of the entire world production. The bulk of the wool is of the fine merino type

South American Merino Sheep

The early livestock husbandry in Argentina was confined exclusively to cattle raising The first sheep of Spanish blood were introduced from Peru in 1587 The first merino to come direct from Spain to Argentina was brought to what is now Uruguay in 1794 This is the same year that the first merino was brought to Australia, but the Uruguayan sheep were not as fortunate as the Australian They were soon lost without any appreciable effect on the sheep population of the country In the latter part of the eighteenth century various lots of merinos were smuggled out of Spain by traders and taken to Buenos Aires These sheep were badly neglected and their descendants were miserably undersized They did not produce good mutton or good wool. However, in

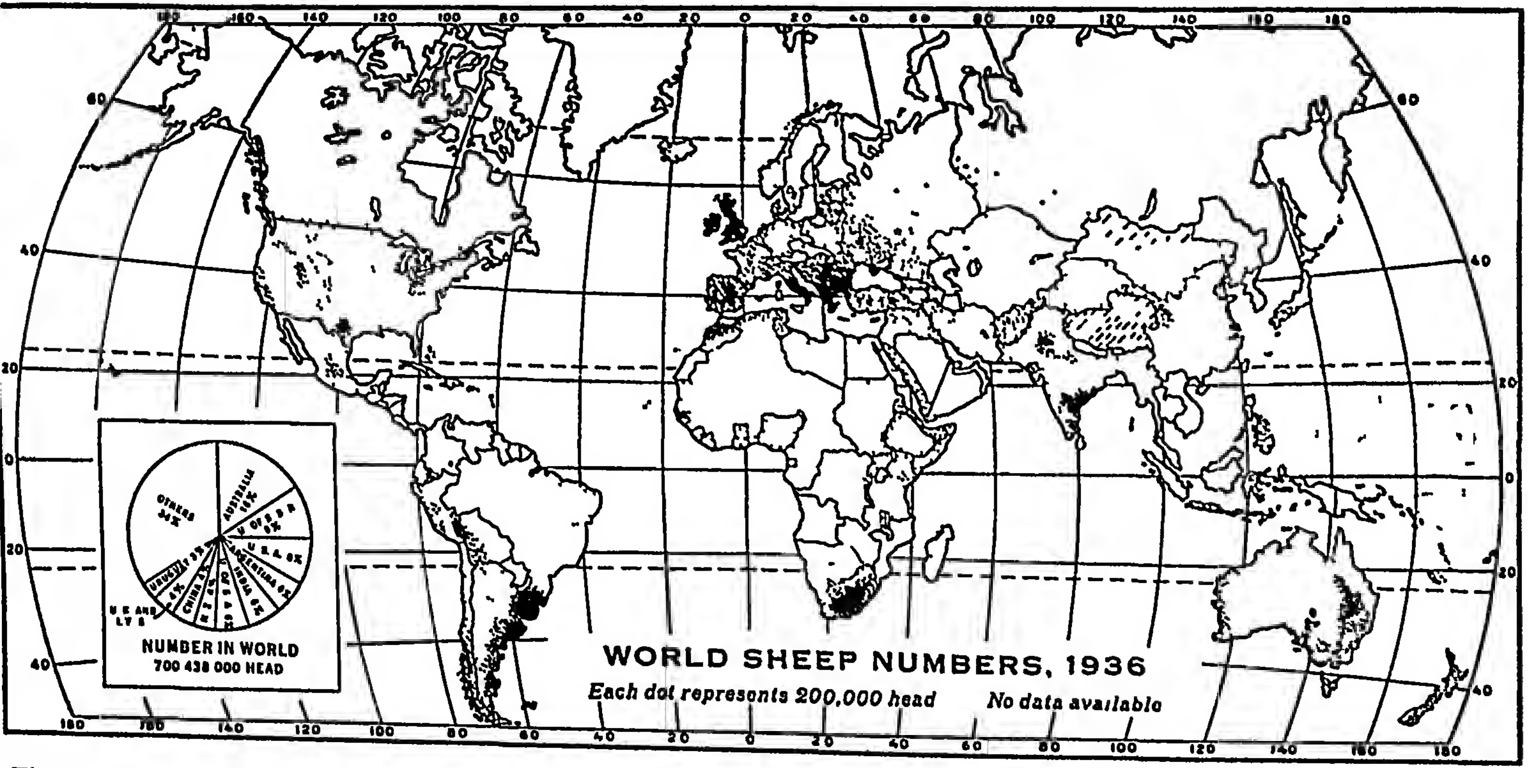


Fig 2 1936 distribution of sheep in the world as reported by the U S Department of Agriculture Concentration points are in Australia, New Zealand, South Africa, South America, Europe, and North America Estimate for 1945 is 720,000,000 sheep in the world.

TABLE 2

NUMBER OF SHEEP IN COUNTRIES HAVING 100,000 AND OVER, AVERAGES 1926-30 AND 1931-35, ANNUAL 1936-41 (*U.S.D.A.*)

Country	Date or Month of Estimate	Averages 1926-30	Averages 1931-35	1936	1937	1938	1939	1940	1941
		Thousands	Thousands	Thousands	Thousands	Thousands	Thousands	Thousands	Thousands
NORTH AMERICA AND WEST INDIES									
United States	Jan. 1	45,596	53,100	51,087	51,019	51,210	51,585	52,399	54,283
Canada	June	3,431	3,442	3,327	3,340	3,415	3,368	3,452	3,550
Mexico	June	3,150	4,545	—	5,240	5,725	6,203	—	—
Guatemala		196	174	233	234	241	231	373	253
Cuba		102	143	154	—	—	—	141	—
Dominican Republic	June	152	152	35	—	40	—	—	—
Estimated total		52,900	62,200	—	—	—	—	—	—
SOUTH AMERICA									
Colombia	Jan. 1	794	868	872	—	831	1,000	—	1,000
Venezuela		125	155	—	62	—	—	—	—
Ecuador		1,190	1,500	735	—	—	600	—	—
Peru		11,209	12,000	—	14,900	—	—	—	12,000
Bolivia	Jan. 1	4,742	5,232	—	—	—	—	5,000	—
Chile	June	6,252	6,083	5,749	6,200	—	—	5,516	—
Brazil	September	10,722	11,576	—	—	14,167	—	—	10,945
Uruguay		20,558	17,552	—	17,931	—	—	20,000	13,000
Paraguay	Jan. 1	400	191	126	145	—	—	—	—
Argentina	July	44,413	40,556	40,200	43,553	45 917	—	—	49,780
Falkland Islands		613	613	604	604	602	—	—	—
Estimated total		100,900	97,100	—	—	—	—	—	—
EUROPE									
Iceland	Spring	625	636	652	635	562	594	—	—
England and Wales	June	15,545	17,486	15,648	17,194	17,913	17,886	—	—
Scotland	June	7,503	7,785	7,557	7,518	7,969	8,042	—	—
Northern Ireland	June	622	783	825	829	893	895	—	—
Total, United Kingdom		24,675	26,046	25,040	25,541	26,775	26,823	—	—
Ireland (Eire)	June	3,425	3,253	3 062	3,000	3,197	3,043	3,071	2,909
Norway	June	1,526	1,725	1,749	1,739	1,775	1,744	—	—
Sweden	July	650	542	425	405	406	373	329	—
Denmark	July	215	179	—	157	—	143	143	—
Netherlands	June	455	601	655	608	651	690	—	—
Belgium	Jan. 1	157	157	—	—	—	153	—	—
France	Jan. 1	10,574	9,512	9,555	9,508	9,994	9,572	8,306	3,432
Spain	Jan. 1	19 925	17,925	—	—	—	21,779	24,237	23,000
Portugal	Jan. 1	4,450	3,274	3,274	—	—	—	3,990	3,900
Italy	April	11,310	9,556	8,982	9,065	9,467	9,554	9,555	10,100
Switzerland	April	170	155	176	—	—	—	—	155
Germany	Jan. 1	3,533	3,476	3,928	4,341	4 652	4,509	4,900	—
Austria	Jan. 1	272	263	263	—	—	318	280	—
Czechoslovakia	Jan. 1	845	515	547	592	644	474	—	—
Poland	November	2,244	2,600	3,024	3,155	3,411	—	—	—
Hungary	April	1,604	1,208	1,350	1,454	1,529	1,565	1,750	—
Yugoslavia	Jan. 1	7,907	8,471	9,211	9,565	9,906	10,137	10,154	—
Greece	Jan. 1	6,551	7,227	8,155	8,440	8,451	8,133	—	—
Albania		1,200	1,503	1,675	—	1,574	1,430	—	—
Bulgaria	Jan. 1	8,384	8,155	8,714	8,431	8,517	8,737	—	—
Rumania	Jan. 1	12,336	12,177	11,928	11,809	12,372	12,768	—	—
Lithuania	June 20	1,344	1,231	1,275	1,285	1,218	1,224	1,263	—
Latvia	June	1,030	1,115	1,352	1,334	1,360	1,462	—	413
Estonia	July	537	538	534	651	650	696	—	713
Finland	September	1,190	973	1,023	1,072	1,073	1,000	—	—
Union of Soviet Socialist Republics		122,752	52,960	64,000	69,000	84,500	—	—	—
Estimated total excluding U. S. S. R.		128,400	123,700	123,263	124,241	130,623	133,904	—	—

TABLE 2

NUMBER OF SHEEP IN COUNTRIES HAVING 100,000 AND OVER AVERAGES 1926–30 AND 1931–35, ANNUAL 1936–41—(*Continued*)

Country	*Date or Month of Estimate*	*Averages* 1926–30	*Averages* 1931–35	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*
		Thousands	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*
AFRICA									
Ethiopia		4,000	1,000	—	—	—	—	—	—
Morocco		8,304	8,026	9,265	10,373	10,162	—	—	—
Algeria	March	6,108	5,312	6,416	6,268	5,965	—	—	—
Libia (Italian)		931	648	533	651	877	877	—	—
Tunisia	Jan 1	2,055	2,967	3,210	3,532	3,383	2,316	—	—
French West Africa		4,563	5,517	5,413	5,316	—	—	—	—
French Sudan		2,576	3,065	3,000	4,800	—	—	—	—
Gold Coast		418	616	617	617	617	—	—	—
Nigeria and British Cameroons		1,976	2,211	1,942	1,920	2,188	—	—	—
Egypt	September	1,138	1,353	1,496	1,919	—	—	—	—
Anglo-Egyptian Sudan		2,160	2,310	2,500	2,500	2,500	2,500	—	—
British Somaliland		1,800	2,500	2,500	3,000	3,000	3,000	—	—
Italian Somaliland	Mar 31	1,165	1,800	—	—	—	—	—	—
French Somaliland Coast		200	356	363	—	—	—	—	—
Eritrea (Italian)		1,216	1,847	1,000	1,000	—	—	—	—
Kenya	June	2,908	3,240	3,255	—	3,294	—	—	—
French Cameroun		216	252	481	480	—	—	—	—
Uganda	Jan 1	831	944	1,051	1,327	1,406	1,445	—	—
French Equatorial Africa		815	1,125	850	898	982	—	—	—
Belgian Congo		282	312	333	—	—	—	—	—
Ruanda Urundi		280	354	350	327	337	—	—	—
Angola (Portuguese West Africa)		124	100	170	—	—	—	—	—
British Southwest Africa		1,249	1,174	2,466	2,898	3,074	3,452	—	—
Bechuanaland	Jan 1	159	176	—	174	200	272	280	—
Union of South Africa	August	43,129	44,054	39,821	41,150	39,118	38,406	41,000	—
Basutoland	Jan 1	2,146	1,884	1,264	1,283	1,470	1,599	1,598	—
Rhodesia Southern	Jan 1	351	340	312	306	319	311	—	—
Tanganyika Territory		2,032	2,122	1,862	1,862	1,616	1,648	1,834	—
Madagascar	Jan 1	131	104	207	208	191	—	—	—
Estimated total		93,800	99,300	—	—	—	—	—	—
ASIA									
Arabia		3,500	3,500	—	—	—	—	—	—
Cyprus	March	259	290	310	299	283	301	—	—
Turkey		11,853	11,555	14,802	16,449	17,760	18,958	18,857	18,905
Iraq (Mesopotamia)	February	4,659	4,514	4,783	4,976	5,514	—	—	—
Palestine	March	249	256	—	209	—	—	—	—
Transjordan		237	220	193	189	200	224	—	—
Iran		15,277	15,003	13,615	14,011	—	—	—	16,000
Syria and Lebanon	Jan 1	2,035	2,289	2,056	2,195	2,274	2,129	—	—
India	Jan 1	38,488	43,412	42,806	42,159	42,047	—	—	—
China		24,000	24,000	16,500	—	—	—	—	—
Philippine Islands	Jan 1	125	124	140	152	165	169	—	—
Netherland India		1,413	1,804	1,337	—	—	—	—	—
Estimated total		112,253	117,107	—	—	—	—	—	—
OCEANIA									
Australia	Jan 1	103,329	111,417	108,876	110,243	113,373	111,058	119,305	122,700
New Zealand	April	27,516	28 793	30,114	31,306	32 379	31,897	31,063	31,752
Estimated total		130,900	140,200	—	—	—	—	—	—
Total of (53) countries reporting all periods to 1939		379,779	394,183	389,927	397,943	408,857	411,329	—	—
Estimated world total, including U S. S R.		742 000	692 700	—	—	—	—	—	—

later years the sheep of Argentina and Uruguay have been much improved, so that today they produce a good quality of wool

The sheep population in Argentina in 1941 was 50,000,000, the production of grease wool 494,000,000 pounds; in Uruguay the sheep numbered 18,000,000, and the production of grease wool was 117,000,000 pounds In both countries the percentage of merino wool is approximately 10 per cent

Development of American Sheep in the United States[3]

Sheep were not known to the American Indians The wool used by the colonists came from animals of imported stock The first sheep were introduced into Virginia in 1608, into Massachusetts about 1630, and are reported to have been introduced into the other colonies soon after they were founded It is not definitely known just what was the breed of these first animals Unimproved English sheep seem to have been the most generally brought over Premiums were offered for the first full-blooded merino that was introduced into the colonies, which was as early as 1785

The first two sheep of the merino type arrived in 1793 in Cambridge, Mass, and the owner, in his ignorance of their value, simply ate them The first full-blooded merino ram actually used for breeding purposes was brought from Spain by Messrs Du Pont de Nemours and Delessert in 1801 The next groups to come were those brought in by Robert Livingston and David Humphreys in 1802 Both men were convinced that this breed of sheep might be introduced with great benefit to our country

William Jarvis, American Consul to Portugal in 1809, seized the opportunity offered by the then current convulsions in Spain and by the lifting of the American embargo, to ship some 4000 sheep to the United States The shipments were begun in 1810, with other large importations following in 1811 Approximately 25,000 merino sheep had been secured in this period The animals were distributed over nearly every state

The acquisition of such a number of pure-blooded merinos laid the basis for substantial production of fine wool As a result of governmental assistance and the formation of agricultural societies, the animals spread westward with great rapidity, reaching Ohio and Kentucky

Attempts to improve the quality of the wool were not limited to the merino During the early years of the century some of the long-

[3] This subsection and the following subsection on types and breeds are from Matthews-Mauersberger, *The Textile Fibers*, New York, John Wiley & Sons, Inc, 1947

wooled varieties, such as the Leicester, were also introduced and spread through New Jersey, Pennsylvania, and New York. Between 1810 and 1814 the number of sheep is estimated to have increased from 7,000,000 to 10,000,000 head. During the depression from 1815 to 1820, which was especially disastrous to the production of fine fabrics, the merino breed encountered a setback

With the beginning of the new decade a general improvement set in and another fine-wool mania started, not in Spanish merino, but in the German Saxony merino. This animal produced an even finer quality of wool than the Spanish merino and, therefore, could be sold for higher prices Introduction in volume began in 1824 and ended in 1826 during which period 3300 sheep were brought in This Saxony merino did not spread so rapidly over the country, and on account of its small numbers its influence was not as great as that of the Spanish merino had been Still, the Saxony merino made a valuable contribution to the improvement of American wool.

The best flocks of Spanish and Saxony merino sheep were concentrated in Washington County, N. Y, Vermont in general, West Virginia, and around Steubenville, Ohio In 1830 the amount of wool produced was enough to supply the needs of all woolen mills at that time Wool growing developed rapidly in western Massachusetts, Vermont, and New York in the 1830s

The first accurate figures available relative to the number of sheep are those for 1840, when the census reported 19,000,000 head The greatest center of sheep production was Vermont The Vermont sheep were notable for the heavy weight of fleece they produced. During the forties, there was a rapid shifting of the sheep industry from the East to the West By 1850 the center of the wool production was in Ohio, which had become the leading sheep-raising state in the Union The sheep farmers remaining in the East reduced their flocks and turned their attention to the production of mutton

During the decade of 1850 to 1860 the westward movement continued, but where the land was level and was easily cultivated the sheep industry was not able to compete with wheat, corn, cattle, and hogs Consequently, sheep raising as a pioneer industry rapidly passed across the level prairies to the Far West Sheep have persisted, however, to the present day on the rough or uneven lands of eastern Ohio and southern Michigan

The first development of the industry in the Far West was in Texas and New Mexico and northward The sheep industry of New Mexico had been in existence since an early date As early as 1700, sheep were driven from New Mexico to California In the

expansion of the western industry, New Mexico was drawn upon for much of the foundation stock, which has been gradually improved by the introduction of merino blood By 1860, there were many sheep in Texas and California

The Navajo sheep in New Mexico are traced back to descendants of the unimproved Churro long-wool breed of Spain These sheep probably accompanied the Spanish explorer Coronado who landed in Mexico in 1504 The sheep were his fresh meat supply on his way through the Rio Grande country and up into the present state of New Mexico

The origin of the present type of Navajo sheep is shrouded in mystery During the Navajo revolt in 1860 the sheep were almost entirely exterminated The War Department later gave a contract to a citizen of New Mexico to replace these sheep, but where he obtained the replacement is not definitely known.

After 1870 there was a rapid expansion in the Far West, where free grazing could be obtained throughout the year This western expansion of the sheep industry continued until most of the range country was overcrowded The maximum number of range sheep seems to have been reached in 1884, that year marks the high point of the industry for the United States as a whole, when the number of sheep reported was 50,627,000, exclusive of lambs

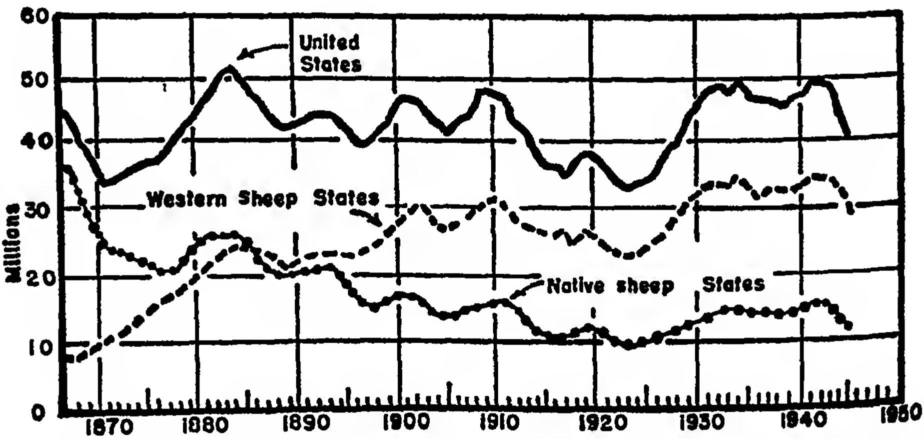


Fig. 3 Stock sheep and lambs number on farms January 1, 1867-1945* Western sheep states include 11 western states, Texas and South Dakota

* Excludes sheep and lambs on feed for market.
Source U S Department of Agriculture.

By 1900 sheep raising in the East was largely confined to areas where, because of much rough land or soil conditions, most of the farm land was only usable for pasture, as in southwestern Michigan and parts of Iowa Since then the sheep industry has been subject to severe competition throughout the country In the East, dairying had continued to make inroads upon the sheep industry, and in those sections of the West where dry farming was important cattle had replaced sheep to a considerable extent

From the early eighties on, the range operators realized that it was profitable to fatten sheep for the market This practice was

TABLE 3

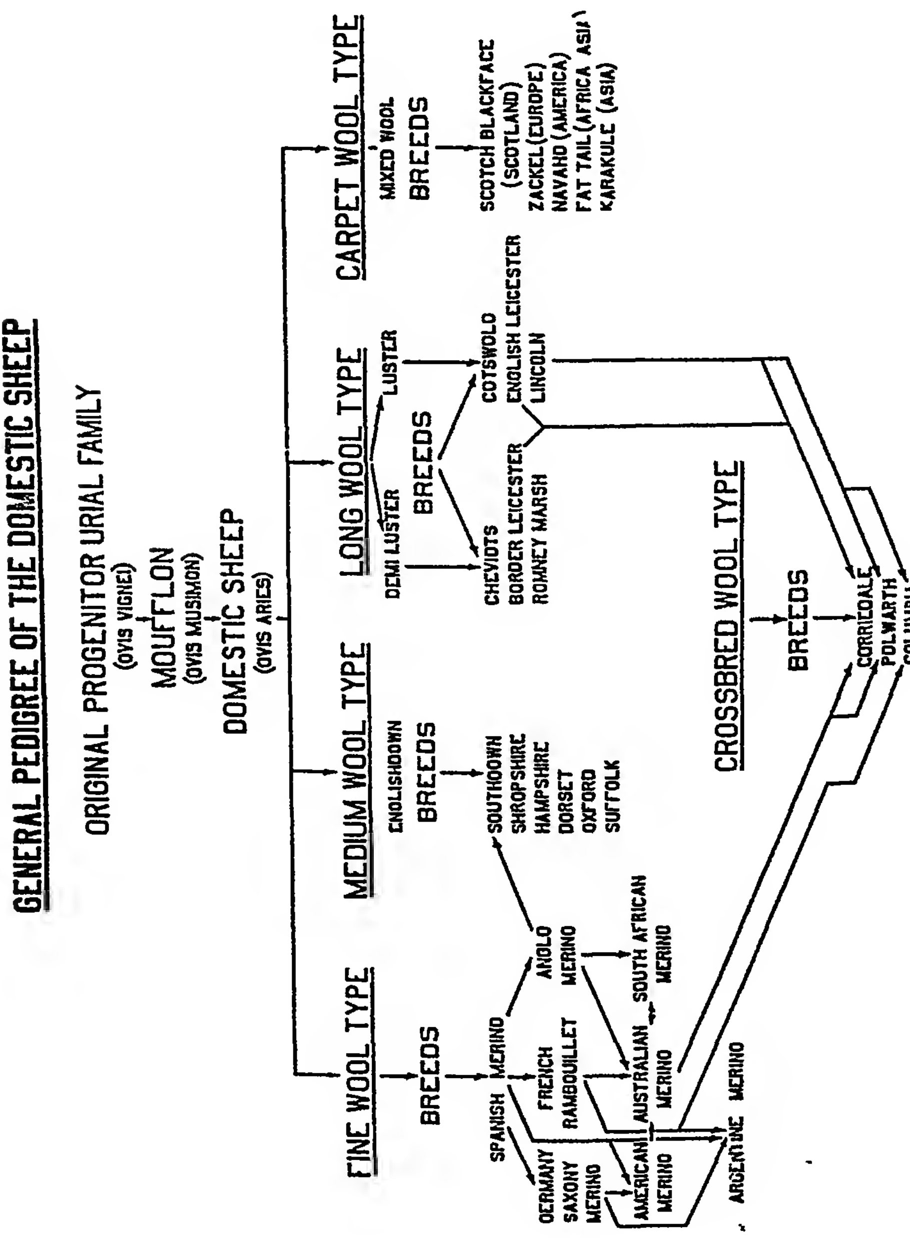
SHEEP AND LAMBS NUMBER AND VALUE ON FARMS, UNITED STATES, JAN 1, 1900–1944

Year	*Stock Sheep*			*Feeder Sheep, Number*	*All Sheep, Number*	Year	*Stock Sheep*			*Feeder Sheep, Number*	*All Sheep, Number*
	Number	*Farm Value*					*Number*	*Farm Value*			
		Per Head	*Total*					*Per Head*	*Total*		
	Thousands	*Dollars*	*1000 dollars*	*Thousands*	*Thousands*		*Thousands*	*Dollars*	*1000 dollars*	*Thousands*	*Thousands*
*1900**	*39,938*	—	—	—	—	1923	32,597	7 50	244,452	4,206	36,803
1900	45,065	2 97	134,046	3,040	48,105	1924	32,859	7 94	260,819	4,280	37,139
1901	46,126	2 96	136,335	2,975	49,101	*1925**	*35,690*	—	—	—	—
1902	46,196	2 62	121,904	3,040	49,236	1925	34,469	9 63	331,971	4,074	38,543
1903	44,436	2 62	116,548	3,100	47,536	1926	35 719	10 53	376,134	4,644	40,363
1904	41,908	2.55	106,961	3,550	45,458	1927	38,067	9 79	372,784	4,348	42,415
1905	40,410	2 77	111,962	3,415	43,825	1928	40,689	10 36	421,582	4,569	45 258
1906	41,965	3 51	147,352	3,560	45,525	1929	43,481	10 71	465,609	4,900	48,381
1907	43,460	3 81	165,371	3,800	47,260	*1930**	*41,780*	—	—	—	—
1908	45,095	3 87	174 650	3,100	48,195	1930	45,577	9 00	410,290	5,988	51,565
1909	47,098	3 42	161,192	3,695	50,793	1931	47,720	5 40	257,742	5,513	53,233
*1910**	*39,644*	—	—	—	—	1932	47,682	3 44	164,245	6,220	53,902
1910	46,939	4 06	190,573	3,300	50,239	1933	47,303	2 91	137,671	5,751	53,054
1911	46,055	3 83	176,431	4,500	50,555	1934	48,244	3 77	181,718	5,259	53,503
1912	42,972	3 42	147,118	4,925	47,897	*1935**	*48,358*	—	—	—	—
1913	40,544	3 87	156,949	4,108	44,652	1935	46,139	4 33	199,705	5,669	51,808
1914	38,059	3 91	148,745	5,030	43,089	1936	45,386	6.35	287,985	5,701	51,087
1915	36,263	4 39	159,146	4,250	40,513	1937	45,422	6 02	273,610	5,597	51,019
1916	36,260	5 10	184,856	3,750	40,010	1938	45,119	6 13	276,671	6,091	51,210
1917	35,246	7 06	248,917	3,640	38,886	1939	45,710	5 75	262,643	5,885	51,595
1918	36,704	11 76	431,679	2,950	39,664	*1940**	*40,129*	—	—	—	—
1919	38,350	11 49	440,730	3,515	41,875	1940	46,558	6.35	295,763	5,841	52,399
*1920**	*35,034*	—	—	—	—	1941	47,804	6 78	323,996	6,479	51,283
1920	37.328	10.59	395,235	3,415	40,743	1942	49,807	8 66	431,542	6,928	56,735
1921	35,426	6.34	224,454	5,053	39,479	1943	48,796	9 69	472,792	6,979	55,775
1922	33 365	4 79	159,839	3,557	36,922	1944†	45,777	8 70	398,101	5,941	51,718

Source U S Agricultural Marketing Service

* Italic figures are from the census Census dates were June 1, 1900, Apr 15, 1910, Jan 1, 1920 and 1925, Apr 1, 1930, Jan 1, 1935, Apr 1, 1940 1900, 1910, 1930, and 1940 exclude spring born lambs

† Preliminary.


GENERAL PEDIGREE OF THE DOMESTIC SHEEP
ORIGINAL PROGENITOR URIAL FAMILY
(OVIS VIGNEI)
MOUFFLON
(OVIS MUSIMON)
DOMESTIC SHEEP
(OVIS ARIES)
FINE WOOL TYPE
BREEDS
SPANISH MERINO
GERMANY SAXONY MERINO
FRENCH RAMBOUILLET
AMERICAN MERINO
ANGLO MERINO
AUSTRALIAN MERINO
SOUTH AFRICAN MERINO
ARGENTINE MERINO
MEDIUM WOOL TYPE
ENGLISHDOWN
BREEDS
SOUTHDOWN
SHROPSHIRE
HAMPSHIRE
DORSET
OXFORD
SUFFOLK
LONG WOOL TYPE
DEMI LUSTER
LUSTER
BREEDS
CHEVIOTS
BORDER LEICESTER
ROMNEY MARSH
COTSWOLD
ENGLISH LEICESTER
LINCOLN
CARPET WOOL TYPE
MIXED WOOL
BREEDS
SCOTCH BLACKFACE
(SCOTLAND)
ZACKEL (EUROPE)
NAVAHO (AMERICA)
FAT TAIL (AFRICA ASIA)
KARAKULE (ASIA)
CROSSBRED WOOL TYPE
BREEDS
CORRIEDALE
POLWARTH
COLUMBIA

encouraged greatly by the development of great packing centers in the upper Mississippi Valley The Far West was shipping sheep to these packing centers It soon became evident that it was profitable to give some of these animals "a better finish" before they were slaughtered The increased demand for mutton caused the wool growers to develop sheep which yielded good mutton as well as good wool

The development of the United States sheep industry since its peak year 1884 is best illustrated by Fig 3 and Table 3

TYPES AND BREEDS OF SHEEP

The domestic sheep is cultivated in every country of the world, and therefore numerous varieties are produced in the various countries Today, there are several hundred different types, which vary considerably in appearance and in the character of the wool they produce The main causes of the numerous varieties are· different conditions of soil, climate, pasturage, crossbreeding, and changing demands on the part of the wool manufacturers

Figure 4 shows the general pedigree of the domestic sheep and its development into the various types Practically all fleece wools can be classified into the five general types fine wool, medium wool, long wool, crossbred wool, and carpet or mixed wool The breed of the sheep influences the character of the wool grown and governs to a large extent the diameter and the lengths of the fibers Other points, such as strength, luster, waviness, color, and shrinkage, vary considerably according to breed In the diagram are listed only the breeds that played a more or less important part in the development of American sheep husbandry In addition to them are the breeds that supply the domestic market with the additional raw material needed

There are approximately thirty breeds of improved sheep that

TABLE 4

BREEDS PREVALENT IN UNITED STATES

Merino	Oxford	Romney Marsh
Rambouillet	Suffolk	Black-faced Highland
Southdown	Columbia	Tunis
Hampshire	Corriedale	Karakul
Shropshire	Cotswold	Ryeland
Dorset	Leicester	Romeldale
Cheviot	Lincoln	

have been brought to fixed types as adapted to the needs of their native countries Of these breeds, thirteen are well established in the United States and a number of others are gaining in popularity The United States census enumerations of 1930 include eighteen breeds of sheep in the tabulations of purebred livestock (see Table 4) All of these eighteen breeds are represented in the area covered by Ohio, West Virginia, and Pennsylvania

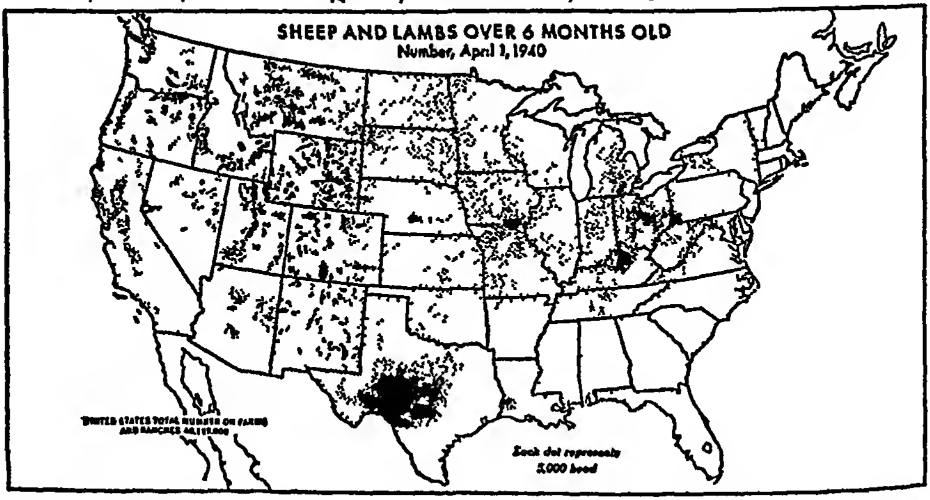


Fig 5 Sheep and lambs over 6 months old On April 1, 1940 there were 8,448,000 sheep in Texas, more than in Wyoming, Montana and Ohio combined

Types of Sheep

The term "type" as applied to sheep is used in various ways In the diagram giving the general pedigree of the domestic sheep the five types classify the breeds according to the type of wool they grow The two main fiber characteristics on which the classification is based are fineness and length The breed of the sheep influences the character of its wool It governs to a large extent the length and diameter of the fibers, and also other physical properties making up the "quality of the wool fiber," such as strength, elasticity, shrinkage, color, luster, and waviness.

In the same way as the breed influences the character of the wool it must be borne in mind that the quality of the meat is affected just as much Therefore, the sheep are also divided into the "mutton type" and the "wool type" Breeds developed primarily for lamb and mutton are grouped under the mutton type, and those developed especially for wool belong under the wool type Whereas

the improvement of the fleeces of sheep by selection and breeding has been practiced for centuries, the development of the mutton breeds was started less than 200 years ago A few breeds are "dual" types developed for both mutton and wool

In Table 5 W. V. Henning applies the two classifications to the most important breeds found in the United States.

TABLE 5

CLASSIFICATION OF TYPES OF BREEDS

Main Types	*Sub-Types*	*Breeds*
Mutton type	Medium wools	1 Shropshire 2 Hampshire 3 Dorset Horn 4 Southdown 5 Cheviot 6 Oxford Down 7. Suffolk 8 Tunis 9 Corriedale 10 Ryeland 11 Columbia 12 Panama 13 Romeldale
Mutton type	Long wools	14 Lincoln 15 Cotswold 16 Leicester 17 Romney Marsh 18 Black-faced Highland
Wool type	Fine wools	19. Merino Class A Class B Class C 20. Rambouillet Class B Class C 21. Tasmanian merino 22 Australian merino

Source. Circular 146, Pa. State College (1934)

In describing the five types of breeds according to the wool—fine, medium, long, crossbred, and carpet—in general terms it must be remembered that each type groups together numerous breeds carrying fleeces which differ widely in some of the properties making up the "quality" of the wool. Under each wool type, some of the characteristic breeds are briefly described.

Fig 6 "A" type Merino ram *Courtesy U S Dept of Agriculture*

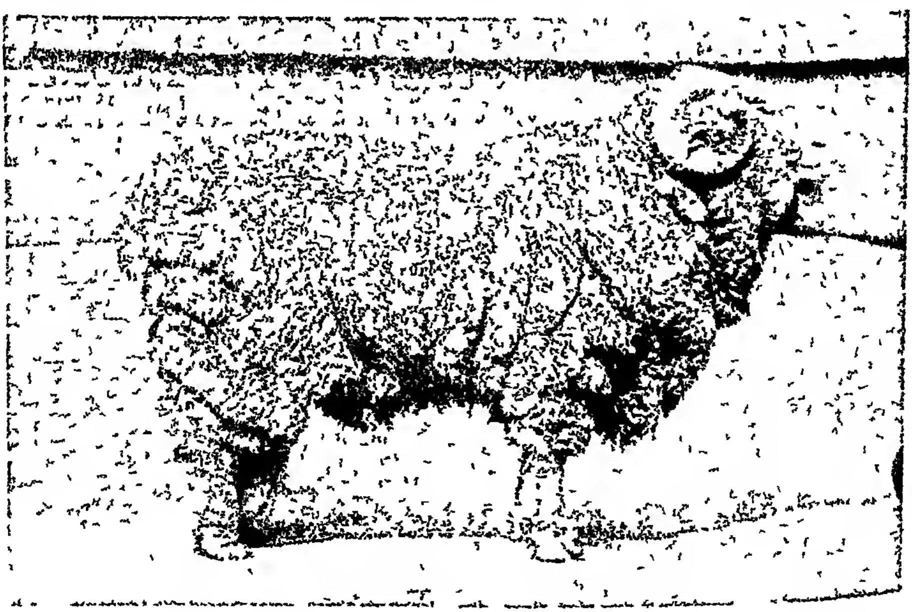


Fig 7 "B" type Merino ram *Courtesy U. S Dept of Agriculture.*

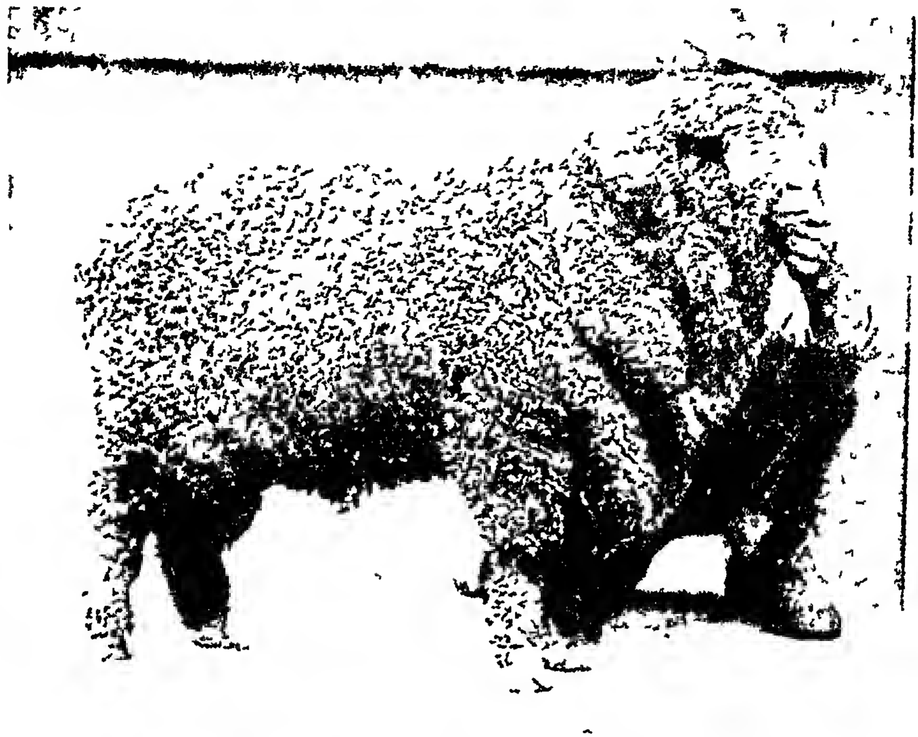


Fig 8 "C" type Merino ram. *Courtesy U S Dept of Agriculture*

Fine Wool Breeds

Only the merino breeds produce fleeces which can be classified under this type. The principal merino families of today are the Spanish, Rambouillet (or French), Saxony, Silesian, Australian, American, South American, and South African.

American Merino The varied experiences the merino has had to go through have steadily molded this breed into types suited to a great variety of conditions Within the merino breed the skin folds on the animal show wide variation Some individuals are covered almost entirely over the body and neck with these folds, whereas some have only a moderate development, and others are almost free of them This made it advisable to recognize and establish three different body types for show ring purposes, depending upon the extent of development of the folds. Types A, B, and C were thus set up, the type A embracing those individuals most heavily folded, the type C the smoothest ones While the type A

merino undoubtedly served a useful purpose in years gone by in increasing the fleece weights of the breed, its usefulness is apparently at an end here and it is rapidly disappearing. Even the type B is fast losing its popularity The density of fleece on the heavily folded types has been bred into the present type C and it has been found that the smooth sheep are more practical for the grower

American merino rams range in weight from 140 to 225 pounds, and ewes from 80 to 150 pounds The Rambouillet is much larger, having a better mutton form The rams range from 200 to 275 pounds and ewes from 130 to 170 pounds Rams of both breeds usually have spiral horns and the ewes have none.

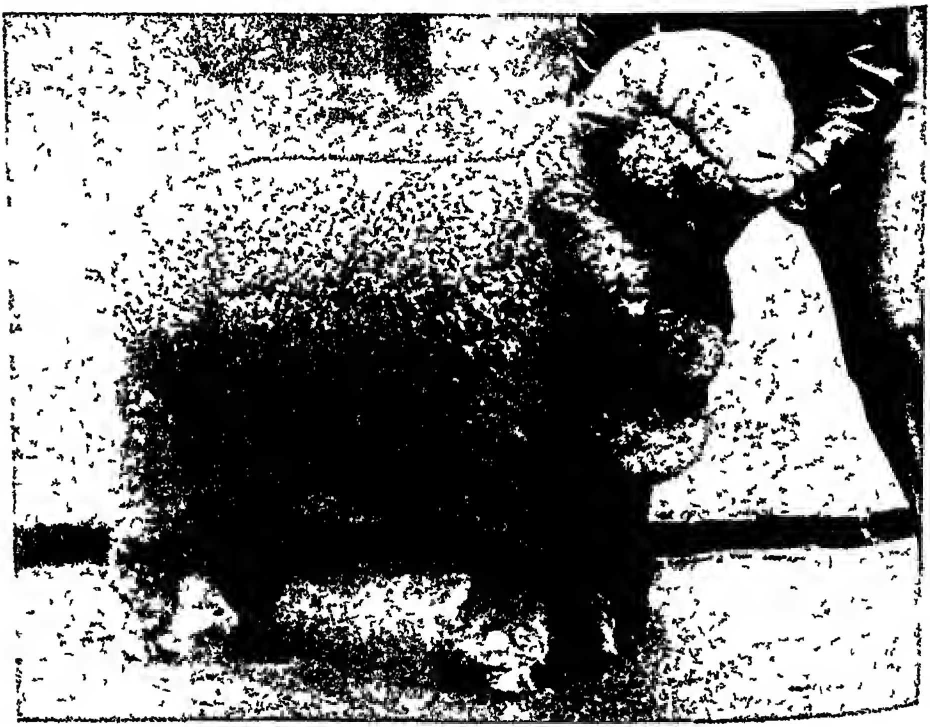


Fig 9 American champion "C" type Rambouillet ewe
Courtesy University of Wyoming.

There is not much difference in size of the American merino breeds and the Australian and Argentinian breeds, as seen from Table 6. The table showing the main characteristics of fine wool type breeds and also the other tables covering medium wool, long

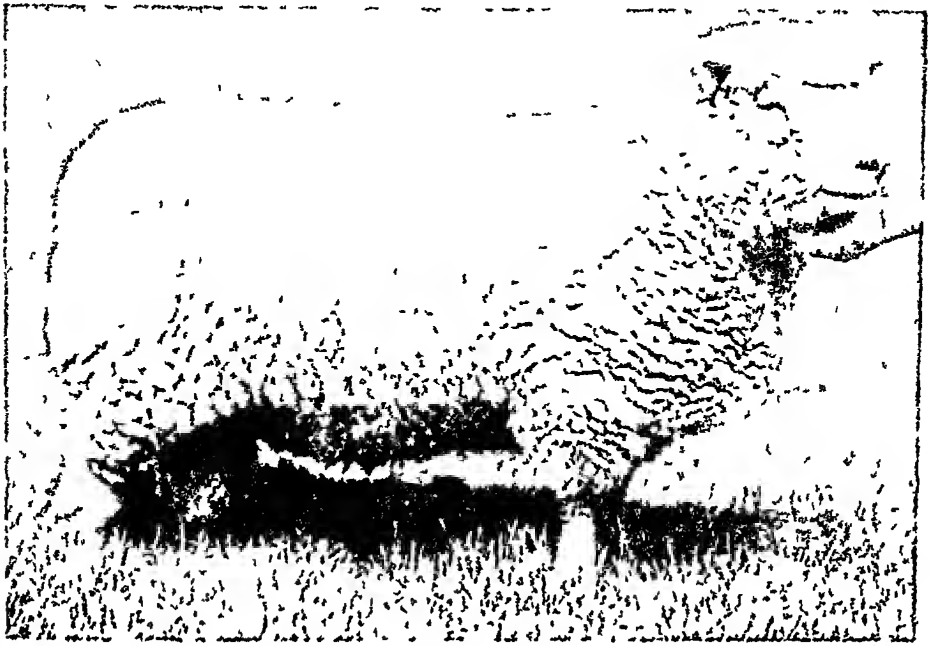


Fig. 10 Southdown ram *Courtesy U S Dept of Agriculture*

TABLE 6

CHARACTERISTICS OF FINE WOOL TYPE BREEDS

Country	*Breed*	*Body Weight (pounds)*		*Weight per Fleece (pounds)*		*Grade*	*Length (inches)*	*Shrinkage in Ewe Fleeces (per cent)*
		Ram	*Ewe*	*Ram*	*Ewe*			
Australia	Fine wool merino	130 to 170	80 to 100	14 to 20	6 to 10	64s to 90s	2¼ to 4	40 to 50
	Medium wool merino	150 to 200	100 to 140	18 to 28	8 to 14	60s to 70s	3 to 4	45 to 55
	Strong wool merino	200 to 260	140 to 180	22 to 34	15 to 18	56s to 64s	3 to 5	50 to 58
United States	Type A merino	140 to 175	85 to 135	20 to 30	13 to 20	64s to 80s	1½ to 2	58 to 70
	Type B merino	140 to 185	90 to 140	20 to 30	13 to 20			
	Type C merino	150 to 225	90 to 150	15 to 25	10 to 18	64s to 80s	2½ to 3¼	
	Rambouillet	200 to 275	130 to 170	15 to 25	10 to 18	58s to 70s	1½ to 3½	55 to 65
Argentina	Type A merino	132 to 165	88 to 120	25 to 35	9 to 22		1¾ to 2	65
	Type B merino	165 to 175	110 to 132	22 to 31	9 to 18	60s to 64s	2 to 2¾	60
	Type C merino	155 to 200	120 to 145	18 to 27	9 to 15		2¾ to 3¾	55
France	Rambouillet 1927	185	100	26	13	64s to 70s	2½ to 3½	

Source Tables 5, 6, 7, and 8 are compiled from various sources.

wool, and crossbred breeds refer to major animals of pure breeding, 2 to 4 years old, in excellent condition, and in twelve-month fleece No attempt has been made to include in the data those rare individuals attaining very unusual size or producing extraordinarily heavy fleeces, Table 6 indicates the normal weight ranges to be expected under conditions set forth above A breed of sheep may attain a certain average size and produce a certain average fleece weight in one part of a country, whereas the same breed grown in another section or in another country may be lighter or heavier and may produce more wool or less, depending on its adaptation to feed, climate, and other local conditions Furthermore, there are strains or families within each breed possessing the propensity for size or the lack of it and for heavier or lighter fleece weights, and, finally, some of the breeds whose fleece weights may seem low have such light-shrinking wool that the clean fiber content may make them fully comparable to others whose fleece weights seem high

Medium Wool Breeds

By far the largest percentage of medium wool is produced by breeds that originated in Great Britain. The following breeds are

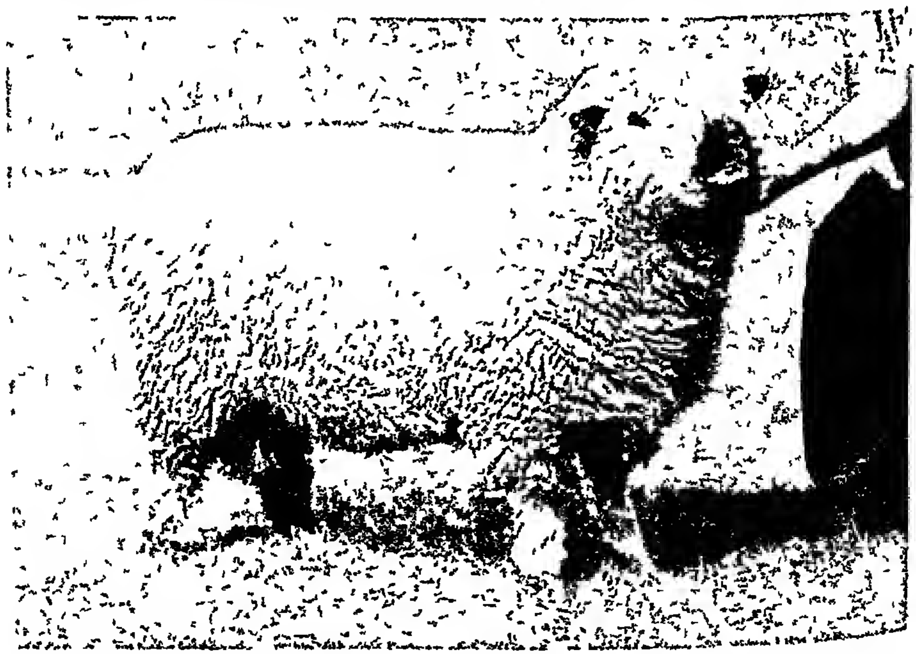


Fig 11 Shropshire yearling ram *Courtesy. U S Dept of Agriculture*

included in the medium-wool class · Southdown, Shropshire, Hampshire, Oxford, Suffolk, Dorset, Cheviot, Ryeland, and Tunis. The first five are collectively referred to as "down" breeds, because of the nature of the country in which they were developed—ranges of hills or "downs" in southern England. The "down" breeds have all

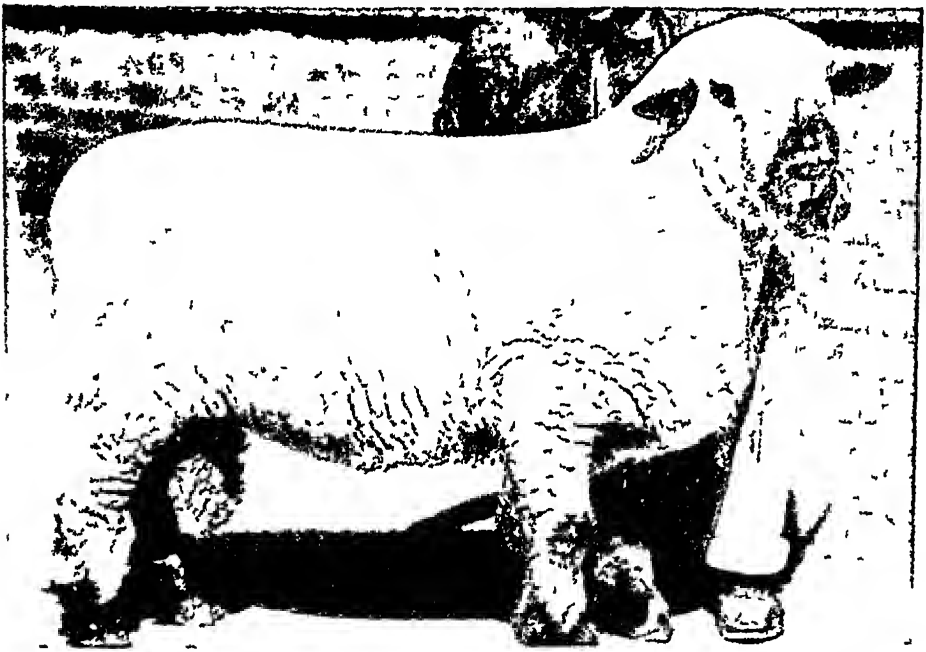


Fig 12 Aged Hampshire ram *Courtesy U S Dept of Agriculture*

been bred primarily for mutton, with special emphasis upon some useful character considered necessary for the style of farming and the markets of the various counties or "shires," from which most of the breeds take their names

The face and leg color of all down breeds is some shade of brown or black, and the fleece occupies a middle position between the length and coarseness of the long wools and the extreme fineness and density of the fine wools While there are breed variations in fineness, length, and density, the fleece is always close and dry enough to furnish excellent protection

Dorset Horn The Dorset is of the medium-wool type but is not a down breed Both rams and ewes have horns and the faces and legs are white It is the only common medium-wool breed in the

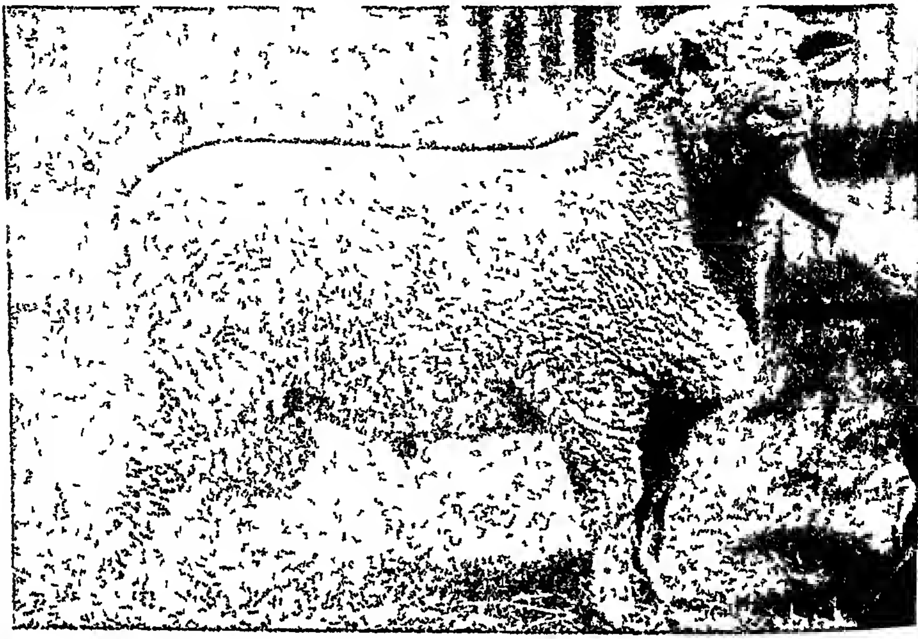


Fig 13 Oxford ram *Courtesy U S Dept of Agriculture*

Fig 14 Dorset ram *Courtesy U S Dept of Agriculture.*

United States that has horns The native home of the Dorset horn is in the counties of Dorset and Somerset in south-central England

Cheviot The Cheviot possesses the characteristics of hill or mountain breeds, it is very active and alert, which indicates that it is well adapted to grazing over rough and rugged country. It is a native of the Cheviot Hills, which form about 30 miles of the border country between England and Scotland The wool is noted for its use in tweeds

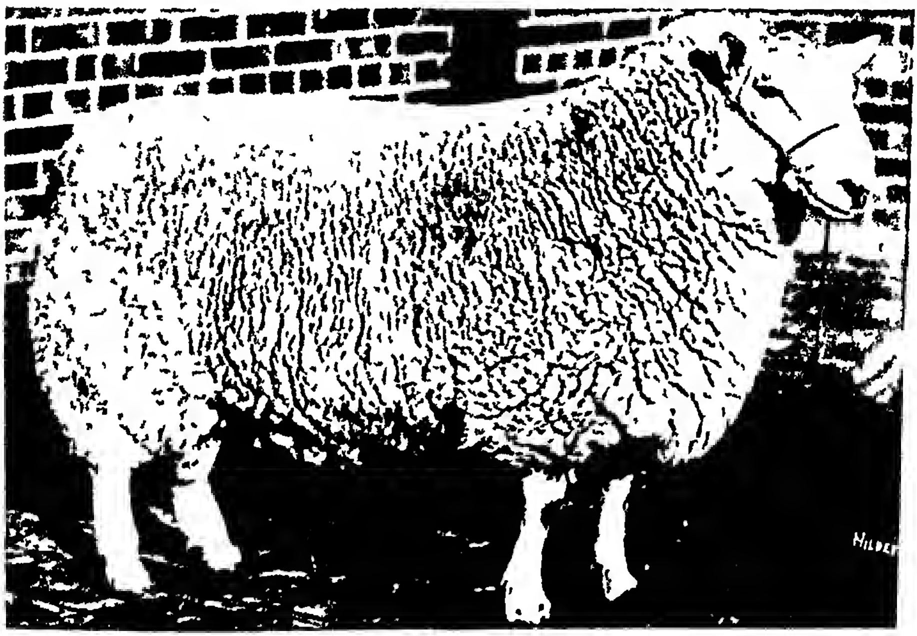


Fig 15. Cheviot ram *Courtesy U S Dept of Agriculture*

Most of the down sheep are today found all over the world, because they can be fattened for the meat market better than any other sheep Southdown and Shropshire rams are sold to Australia, New Zealand, Argentina, Chile, Peru, the West Indies, the United States, Canada, Kenya, the Scandinavian countries, Japan, and China In the United States over 50 per cent of all breeds are down sheep.

TABLE 7

CHARACTERISTICS OF MEDIUM WOOL TYPE BREEDS

Breed	Body Weight (pounds)		Wool Weight per Fleece (pounds)		Grade	Length (inches)	Shrinkage (per cent)
	Ram	Ewe	Ram	Ewe			
Southdown	140 to 180	90 to 140	5 to 8	4 to 7	56s to 60s	2	45 to 56
Shropshire	150 to 225	120 to 170	6 to 10	5 to 9	48s to 56s	2¼ to 3	
Hampshire	170 to 275	135 to 200	5 to 9	4 to 8	48s to 56s	2½	
Suffolk	225 to 300	165 to 225	6 to 9	5 to 7	48s to 56s	2 to 2¾	38 to 50
Oxford	250 to 325	180 to 250	12 to 15	10 to 12	46s to 50s	3 to 4	
Dorset Horn	150 to 225	125 to 150	6 to 9	4 to 7	48s to 56s	2½ to 3	
Cheviot	150 to 200	115 to 150	7 to 10	6 to 8	48s to 56s	4	35

Long Wool Breeds

The long-wool breeds—Lincoln, Cotswold, Leicester, and Romney Marsh—bred chiefly for mutton, are the largest sheep of all breeds All of them are large-framed, square-bodied sheep, with very broad backs Their fleeces are open or loose, as compared with the fine wools and medium wools, and are coarser and very long As their size indicates, the breeds of this class have been

Fig 16 Lincoln ram. *Courtesy U S Dept of Agriculture*

developed for level lands, where feed can be obtained without much travel With proper attention they will thrive upon lands that are too low and wet for the breeds of the medium-wool class (though the keeping of any sheep on marshy ground is not advised) The long-wool sheep have been found to thrive in regions of excessive rainfall because the long wool carries the water off the body

Lincoln This breed, the largest of all sheep, originated in Lincolnshire, the low country on the east coast of England. The face and legs are white with the exception of the hoofs and the skin at the lip and nostrils.

The wool covers the body in broad locks with a characteristic curl on the outer end It forms a tuft on the forehead, but does not extend over the top of the head above the eyes The Lincoln leads the mutton breeds in length of wool In the United States its distribution is limited to Oregon and to the Mountain States, where over 80 per cent of all Lincolns are bred The breed is very popular in Argentina, Australia, New Zealand, and Canada

Cotswold The typical Cotswold is a big-bodied, rather tall sheep

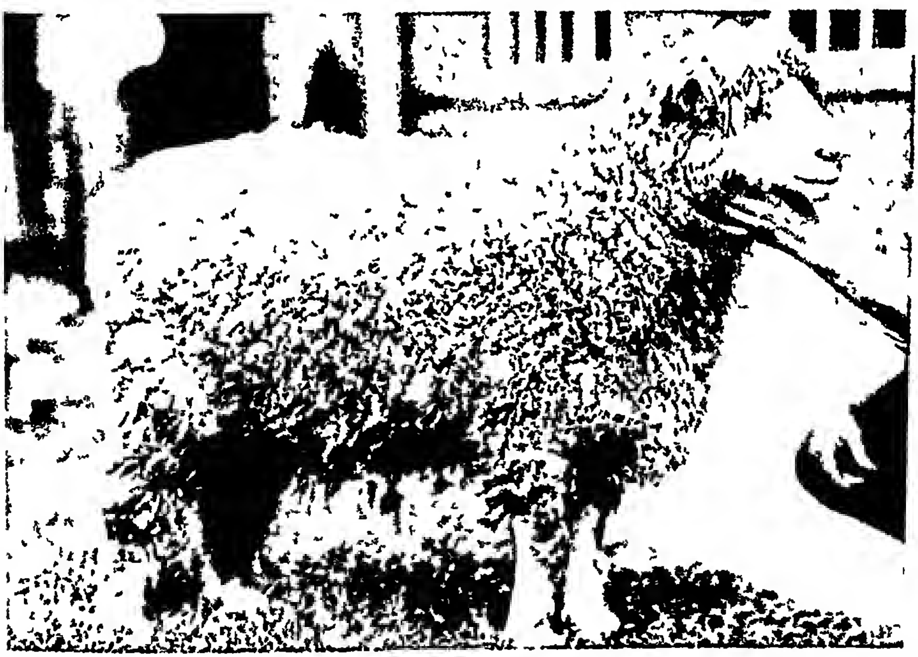


Fig 17 Cotswold ram *Courtesy U S Dept of Agriculture*

of stylish appearance Its native home is the Cotswolds, a hilly area of Gloucester, England The Cotswold sheep resembles the English Leicester The face, ears, and legs are white, or white mixed with a little brown The wool extends up over the poll and hangs in ringlets of various lengths over the face All over the body the wool hangs in wavy ringlets 10 to 14 inches long that do not show in the same way on any other breed, with the exception of the Angora goat; one fleece will shear from 10 to 14 pounds. The shrinkage is low because there is no excess of grease, and the quality is coarse, grading usually "braid." The Cotswolds are most popular in Oregon and the Mountain States

Leicester. The breed commonly known as Leicester is divided into English-Leicester and Border-Leicester. The English-Leicester is well covered with wool at the crown of the head, similar to the Cotswold, whereas the head of the Border-Leicester is bare of wool In the United States and in Canada breeders have mixed Cotswolds and Leicesters

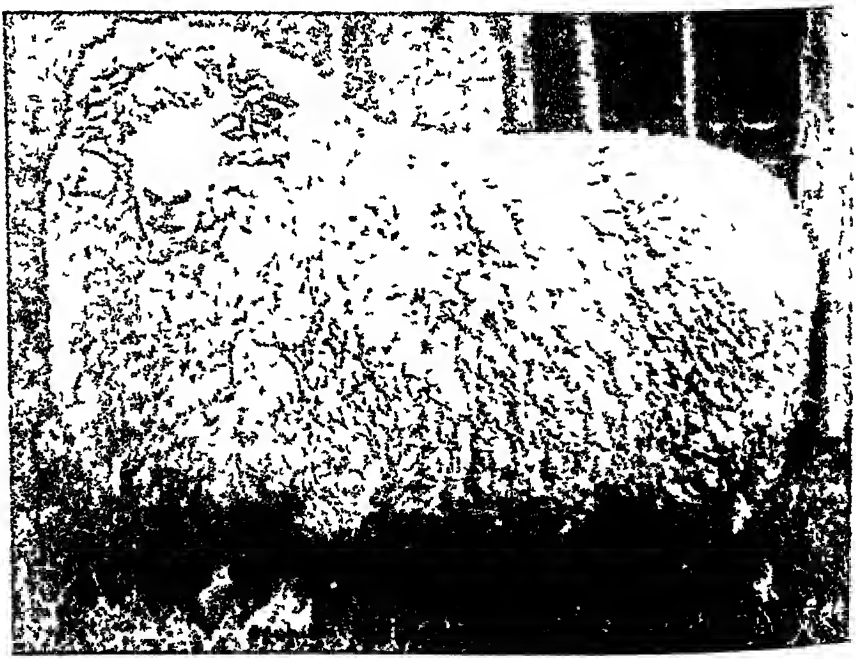


Fig. 18 Romney ram of New Zealand.
Courtesy. J F Wilson, Univ. of California

Romney The Romney, which originated in the plain of southeastern England, is popular in Oregon, Washington, and California and is widely distributed in South America, Australia, and New Zealand. The wool is not as long nor as lustrous as Cotswold or Lincoln, but is denser and finer, grading low quarter-blood to quarter-blood Rams range in weight from 225 to 250 pounds and ewes from 175 to 200 pounds Shrinkage is 20 to 35 per cent

TABLE 8

CHARACTERISTICS OF LONG WOOL TYPE BREEDS

Country	Breed	Body Weight (pounds)		Wool Weight per Fleece (pounds)		Grade	Length (inches)	Shrinkage (per cent)
		Ram	Ewe	Ram	Ewe			
United States	Lincoln	300 to 350	200 to 250	16 to 22	12 to 16	36s to 46s	8 to 12	20 to 35
	Cotswold	250 to 275	200 to 250	14 to 20	10 to 12	36s to 40s	10 to 11	
	Leicester (English)	225 to 250	175 to 200	10 to 15	9 to 12	40s to 48s	6 to 8	
New Zealand	Romney	225 to 250	150 to 190	22 to 26	10 to 12	44s to 50s	5 to 6	25 to 30

Crossbred Wool Breeds

The crossbred breeds produce medium-fine wool and are, therefore, often classified with the medium-wool breeds The breeds representing these groups were developed in the last fifty years by crossing merino or Rambouillet with long-wool sheep In the United States, the following breeds were developed by crossbreeding the Columbia, Panama, and Romeldale

Corriedale The Corriedale, which is the oldest of this class of sheep, has been developed in New Zealand since 1880 Lincoln rams were crossed with merino ewes, and, after close culling toward the desired type, the half-breeds were mated The type is practically intermediate with the Lincoln and the merino, being smaller and less heavily fleshed than the Lincoln and larger and more heavily fleshed than the merino The fleece possesses much of the fineness and softness found in the merino, but with much greater lengths than occur in the same grades with other fleeces

This breed is most valuable where sheep are bred equally for lambs and wool under range conditions The face, ears, and legs are white, and in other breed characteristics it is similar to the two amalgamated parental breeds The fleece obtains a length of 3 to 4

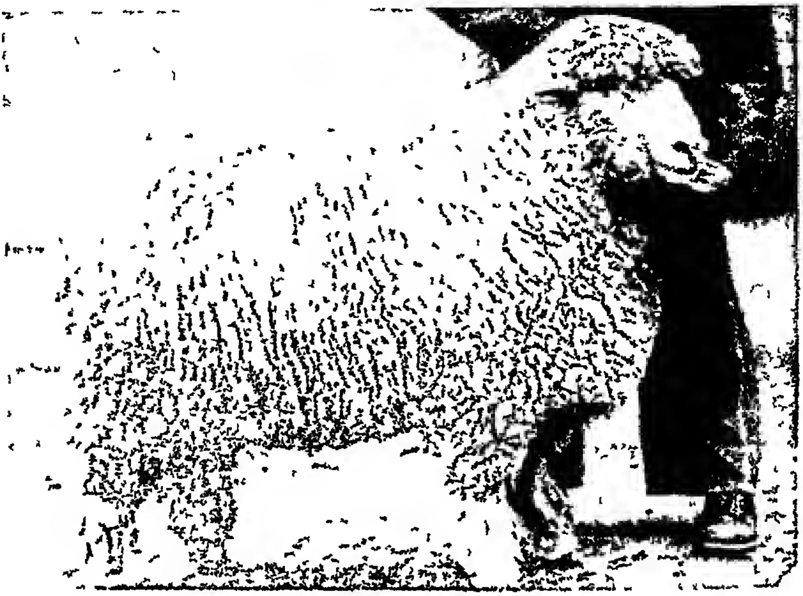


Fig 19 Champion Corriedale ram *Courtesy Univ. of Wyoming*

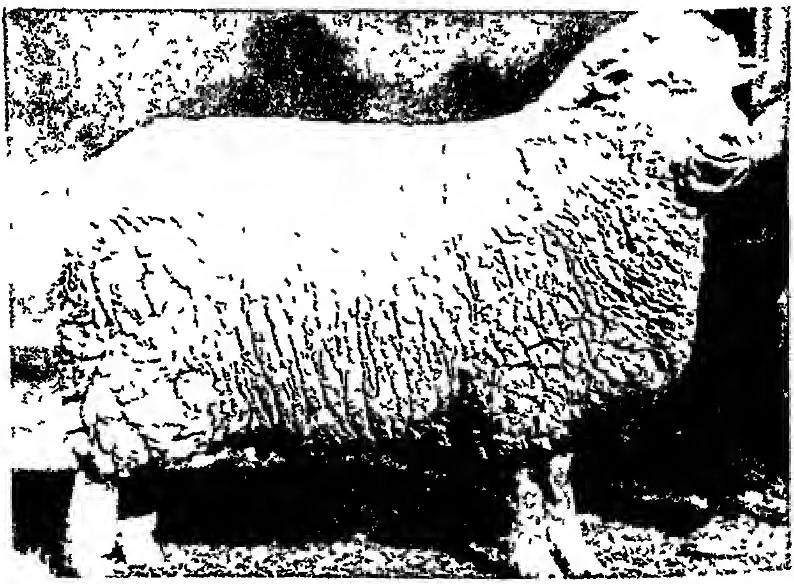


Fig 20 Columbia ewe
Courtesy U S Experimental Station, Dubois, Idaho

inches and weighs from 10 to 12 pounds The quality grades are quarter-, three-eighths-, and one-half blood, and shrinkage is less than in most other wools of similar quality. The breed is increasing in popularity in the western ranges and is most common in Wyoming, California, and Oregon

Columbia The Columbia is a crossbreed of Lincoln rams and Rambouillet ewes developed by the Bureau of Animal Husbandry, United States Department of Agriculture The development work was begun in 1912 at Laramie, Wyo, and since 1917 has been continued at the United States Sheep Experiment Station, Dubois, Idaho The purpose of this work was to develop a crossbred sheep suitable to western range conditions that would breed true to type.

The Columbia is a large, vigorous, and heavy-boned animal with rather long legs Ewes average about 135 pounds and rams up to 275 pounds under normal range conditions Columbia ewes are very prolific They consistently yield long-stapled fleeces of three-eighths- or quarter-blood quality During a three-year period the fleece weights of mature Columbia ewes, under strict range conditions, averaged 11 27 pounds For the same period 75 74 per cent of the ewes each produced and weaned one lamb annually These lambs averaged 78 02 pounds in weight at weaning time.

Panama The Panama is similar to the Columbia breed It was started in 1912 by James Laidlaw of Muldoon, Idaho In this case, Rambouillet rams were bred to Lincoln ewes

Romeldale This breed was developed by the Spencer Ranch Company of Cranmore, Calif, by mating Romney rams with Rambouillet ewes Through careful selection of the crossbreeds in all these cases a type of sheep has been introduced which is about halfway between the two parental breeds

Polwarth The Polwarth originated in 1880 in Victoria and Tasmania from pure Australasian merino mated with a pure Lincoln. In Australia they are known as "comeback" sheep The Polwarth produces even quality, high yielding wool, about 58s grade and 4 to 6 inches long The breed is considered a valuable animal by Argentina breeders for their country.

TABLE 9

CHARACTERISTICS OF CROSSBRED WOOL TYPE BREEDS

Country	Breed	Body Weight (pounds)		Wool Weight per Fleece (pounds)		Grade	Length (inches)	Shrinkage (per cent)
		Ram	Ewe	Ram	Ewe			
United States	Corriedale	150 to 250	125 to 145	15 to 19	10 to 12	50s to 60s	3 to 4	45 to 56
	Columbia	175 to 275	135 to 155	15 to 20	10 to 12	50s to 56s	3½	50
	Panama	200 to 275	145 to 160	16	10 to 12	50s to 58s	3 to 3½	45 to 50
	Romeldale	175 to 225	115 to 150	12 to 17	8 to 11	58s to 60s	3½ to 4	40 to 45
	Targhee	200	130	—	11	58s to 60s	3	45
	Thribble Cross	200	150	15	10	56s to 58s	3	45
Australia	Corriedale	175 to 275	130 to 160	17 to 26	10 to 11	48s to 56s	4 to 7	35 to 40
	Polwarth	125 to 175	110 to 125	12 to 18	8 to 10	50s to 64s	4 to 6	30 to 35
New Zealand	Corriedale	175 to 250	125 to 150	18 to 24	10 to 14	50s to 58s	4 to 6	30 to 40

Carpet or Mixed Wools

Carpet wools are produced by sheep which live under primitive conditions in all parts of the world. A large proportion of the carpet wool comes from the Asiatic countries, and the preponderance of the sheep from which these wools come are of the fat-tailed and broad-tailed varieties, although some carpet wool is produced by sheep of the thin-tailed varieties

The merino sheep has left its imprint on nearly all the European countries, North and South America, Australia, and South Africa In Asia it has made but little progress, for here the prevailing sheep is quite a different animal carrying a distinct type of fleece

As the urial sheep migrated across arid deserts in the summer and through barren wastes in the winters, such features as fat tail, broad tail, fat rumps, long legs, and big horns were developed Fat-tailed sheep are found in desert regions, where they have to live on little food during certain periods and are able to survive on the store of fat carried in their tails

Fat-rumped sheep grow two lumps of fat, one on each buttock, but they have very short tails, which in some cases do not exceed 3 inches in length These animals often weigh 200 pounds each and have from 30 to 40 pounds of fat Long-legged sheep live on the lowlands Their length of leg enables them to cross marshy ground with speed and ease

The wool grown by these sheep is composed of a mixture, a long hairy outer coat protecting the finer undercoat of true wool which keeps the animal warm This type of fleece protects the sheep

against low temperatures, high winds, and extremes in moisture ranging from extreme dryness to excessive rain and fog

Representative of the Asiatic breeds producing carpet wools are the Somali, fat-rumped, Hirrik, and Sikkim Bera breeds, for which the following descriptions are given.

Fat-Rumped This breed and its several sub-breeds or local breeds are an "Asiatic" type which ranges from the Black Sea and the confines of Europe, throughout central Asia, and through the greater part of China and Siberia Enormous flocks are kept by nomad Kirghiz, Kalmuks, and Mongols In Siberia they are largely bred by Russians In China the fat-rumped sheep appears to be almost the indigenous domesticated breed of sheep Some flocks include 10,000 to as many as 15,000 head In many districts the breed is not pure but has been crossed with sheep of other kinds, so there is great variation in the amount of fat on the rump and in

Fig 21 Arabian fat-tailed sheep—Iraki or Hirrik
Courtesy California Wool Growers Association

the length of tail The Tatarian breed, which extends from the Kirghiz Steppe to southern Siberia, is a typical representative of the groups The urial is thought to be the original ancestor of the fat-tailed and fat-rumped groups

Hirrik or Iraki This breed is not only one of the best examples producing carpet wools but is also a good representative of the Arabian sheep family The breed is hornless and belongs to the fat-tailed group with the tail rather flat and oval in shape The coarse wool is quite long and white and extends over the top of skull The head, ears, and legs are brown, with some exceptions that are black or mottled in color Rams average 4½ pounds and ewes 3 pounds of wool per year Thousands of this type of sheep supply the Syrian and Palestine mutton markets

Sikkim-Bera This breed is a native of Sikkim, a native state of India It thrives well from sea level to an altitude of 18,000 feet A ram has an average height of 2 ft 6 in and an average length of 3 ft 6 in from base of horns to root of tail The wool is

Fig 22 Scotch black-face mountain sheep
Courtesy. Eavenson & Levering Co.

very coarse and ashy Annual shearing is from 2 to 4 pounds When left to natural grazing, 60 to 70 pounds of meat is obtained from a ram Ewes measure slightly less and give less wool

In addition to these Asiatic breeds, there are a number of European breeds producing carpet types of wool. The best known belong to the British mountain sheep such as the Scottish blackface and Welsh mountain.

Scotch Blackface The Scotch blackface is a well-known mountain sheep of Scotland This breed extends from the Grampians to Pentland Firth, to the Hebrides, the Shetlands, and the Orkneys, and to the heathery moors of Yorkshire and Lancashire in England These sheep are wild, extremely hardy, and impatient of restraint, the ewes make good mothers The breed is medium-sized, it matures quickly and responds quickly to a favorable habitat Crossed with Border-Leicester, these sheep produce excellent market lambs Their wool is long, strong, durable, and elastic, it is much used in carpet making They have a fine carriage The Scotch blackface is horned, has a bare face, a long hairy mottled black-and-white fleece, and bare legs Shrinkage is 30 per cent.

Welsh Mountain The Welsh mountain sheep is a small active animal which has a fleece of rather poor wool seldom exceeding 2 pounds in weight The small carcass of this animal is very solid and forms a notable type of mutton These sheep have tan-colored faces which are taken as an indication of their hardy constitutions They are good climbers and cannot be restricted by walls and fences The rams have horns, but the ewes are hornless Several attempts have been made to improve the breed by Southdown influence, but they have not proved very successful, although Wiltshire rams make a suitable cross These sheep have to be sheared early in the summer as they tend to shed their fleeces in the warmer weather Certain flocks of black Welsh mountain sheep are maintained to supply wool for the Welsh flannel trade

The Navajo In the United States the only sheep producing carpet wools are the Navajo sheep The sheep is quite small The rams of the flocks supervised by the United States Department of Agriculture weigh between 135 and 185 pounds and the ewes between 75 and 150 pounds The ram fleeces range in weight from 5 to 9 pounds and the ewe fleeces from 3 to 6 pounds, yielding from 65 to 70 per cent clean wool The fleeces are composed of an undercoat of true wool fibers from 3 to 7 inches long and an outer coat

of long wool fibers from 7 to 11 inches long The weight percentage of the undercoat ranges from 60 to 80 per cent In common with other unimproved wools, the fleeces contain varying quantities of kemp and other medullated fibers

Fig 23 Navajo ewe from Fort Wingate, N M
Courtesy U S Department of Agriculture

The nearly 50,000 Navajo Indians make their home in a reservation area of about 16,000,000 acres in northeastern Arizona, northwestern New Mexico, and southern Utah, and their main occupation is sheep raising The number of mature sheep and goats on the reservation is about 550,000 head Approximately 750,000 pounds of wool, or about one fourth of the total annual production on the reservation, is woven by the women into blankets and rugs In 1939 not more than 5 per cent of the wool produced was of the Navajo type

SHEEP RAISING

Most of the world's sheep are raised either on large ranches, where they form the single item of profit, or on small farms in connection with dairy or other products The former is the prevailing method in Australia, South America, and the western United States, while the latter prevails in such regions as the Middle West, England, and Continental Europe In addition, large numbers of sheep are raised by primitive methods in remote mountain districts such as the Highlands of Scotland, the Pyrenees, and the plateau of central Asia These are unimproved native varieties, and their wool comes under the heading of carpet wool

In the United States sheep are raised either on small farms or on

large ranches The 100th meridian may be taken more or less as the border line between the two methods of sheep raising From the 100th meridian east, sheep raising is conducted on a small flock basis, westward the range sheep in flocks of thousands are the prevailing type

Eastern-Farm Sheep Raising

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The average farm flock varies in size from twenty-five to fifty ewes Flocks of less than twenty ewes are uneconomical from the standpoint of the caretaker's time and the investment in rams and equipment Sheep raising does not require extensive equipment or heavy labor but it does require continuous attention The sheep will eat ninety out of every 100 kinds of plants that grow, which makes them valuable in cleaning fence land, road shoulders, and weeds in general At the existing wool prices, the wool returns will pay for the keep of the ewes, leaving the money received for lambs as profit Most of the sheep farms are found in hilly or rough areas where the land is unsuitable for other agricultural enterprises In the farm flock states nearly all of the main breeds are raised, but vary as to location and particular type of sheep raising conducted in the locality Growing of the medium wool type or mutton sheep prevails Most of the farms are enclosed with fences and adequate shelter is provided In Pennsylvania, New York, West Virginia, Michigan, and especially Ohio, numbers of fine wool sheep are raised

The problems the sheep farmer encounters vary according to state and location, but there are some of a general nature The most troublesome is the loss encountered from sheep-killing dogs That this is a very acute problem is proven by the fact that in some Michigan counties it has been necessary to appoint special county dog wardens

There are three classes of sheepmen in the farm flock states (1) those who keep purebred flocks to supply purebred breeding stock, (2) those who keep commercial flocks or raise lambs for the market, and (3) those who are classified as commercial feeders

Special care and attention is given to proper breeding which is most important for producing even wool as well as good lambs A careful farmer will only use purebred rams and it seems best to use one ram to every twenty-five to thirty ewes

Western-Range Sheep Raising

In the western states where the range sheep are raised, no stand-

ard or uniform method is followed in the management of sheep The range country varies greatly in soil, topography, climate, and vegetation The range may be a desert like the Red Desert section in Wyoming, or the level or rolling plains type, or the foothill or mountain type The range feed may consist mostly of grass or of a variety of wood plants, shrubs, or small trees known as "browse" Most ranges have good and poor grazing periods as the result of climatic conditions such as wet and dry or hot and cold seasons. Different systems of range management are necessary in the three natural divisions of the range states. the southwestern, central, and northwestern areas

In the southwestern area, the sheep are generally ranged the year around In some irrigated sections of Arizona and California the ewes are lambed early in the fall or early winter for the purpose of producing early spring lambs for the market In the central range areas such as Wyoming and Utah, the sheep are moved to higher altitudes in the mountains in the summer and brought back to the lower ranges in the winter The winter range consists of low plains that are so poorly watered that they can only be utilized when stock water is available in form of snow The plants growing on these plains mature into cured feed during the winter In the northwestern area only a small proportion of the sheep are ranged the year around which makes it necessary, generally, to use a combination of range and ranch The sheep graze on the sagebrush plains of the public domains in the spring, in the mountains and forests during the summer, and on leased or private grazing lands during the fall and winter In this region there are two systems of management, early lambing in sheds, and late lambing on the spring range The best ranges are the ones with sufficient differences in altitude to furnish fresh feed during the summer as the sheep follow the snow line upwards

The prevailing breeds in the range country are the merino and the Rambouillet The flocking instinct is a necessity in sheep that are to be herded in large bands over a vast expanse of open country, and this instinct is characteristic of the fine-wool breeds. Only sheep that are strong and rugged and have enough vigor are able to survive the long hard trails that they have to follow in a year's course to gather their feed In addition, they have to carry sufficient fleece to furnish protection against storms and cold weather In earlier days the merino was the universal range sheep but the Rambouillet or French merino, which was especially selected for and developed in the West, has replaced it today.

Where winter feed is abundant the mutton-type sheep has gained considerable ground, because the return on the lambs is normally much higher than on wool The Corriedales are the favorite breed, also, the Hampshire and the Suffolk rams are used to an increasing extent for breeding.

Herding Sheep on the Range

How many sheep will graze satisfactorily together depends entirely on the character of the range, whether it is plain or mountainous The standard herd or band consists of 1200 ewes with lambs On heavy timber or rough or brushy ranges, as few as 750 ewes may be run to a band, whereas dry sheep are run in bands of 2000 to 3000

The herding difficulties which may be encountered by the shepherd are dependent on the uniformity of the herd, as mixed bands are difficult to herd For example dry ewes and ewes with lambs do not graze evenly The dry sheep covering more ground, getting first chance at the fresh feed, will cause the lambs to travel hurriedly so that they miss the choice feed and become stunted Also, mixed breeds such as Corriedale or Rambouillet do not graze or herd uniformly The herder in charge of a band of sheep has to move them to fresh pastures every four to six weeks, describing a circle around the edge of the range in the course of a year. The herder's only partner in this work is a dog

This steady movement necessitates a high degree of mobility for the herder and his belongings, and the answer to this is the famous canvas-covered sheep wagon, the home of the herder The sheep wagon is moved with the sheep by the camp tender or by the herder himself if he has a team at his disposal Not all herders have a wagon, in fact, there are many other kinds of herding There is herding from the ranch, which means that the herder lives in the ranch building and takes the sheep out to graze during the day and returns them to the corral at night Herders, who have to bed their sheep in a different spot every night, sometimes have a pack horse with which to carry their bed and provisions from place to place

The yearly cycle of the range sheep starts in fall just prior to the breeding season The ewes flock is culled from weak and sick animals and the discarded are shipped to the market with the last of the lambs The ewes suitable for breeding are taken to a choice range and the bucks turned in The bucks are left with the band for thirty days and then taken out, and may under certain conditions be turned in again after a period of from four to seven weeks

As soon as deep snow covers the range, the sheep are taken to winter quarters and are fed hay, which may be supplemented by cotton seed cake or grain when necessary Range lambing ewes are bred so as to lamb in the early spring when the weather is apt to be favorable and the range feed good Newly born lambs and their mothers are left behind their band to be picked by a separate band following, as lambing is not all done at one place

To avoid heavy losses, of late years the shepherd has found that it pays to have shelters available during the lambing season In sections where shed lambing is practiced the spring and early summer ranges must be good The sheds are usually canvas-covered to permit full ventilation The interior of the shed consists of long rows of individual lambing pens During the lambing season the drop-band is kept in the neighborhood of the shelter during the day, each newly born lamb and its mother are brought by extra help known as "lambers" into the small pen inside of the shed There they receive immediate attention from a caretaker They are permitted to remain in the lambing pen from one to three days, after that the ewes and the lambs are returned to the band

After the lambing time is over the shearing season begins The time for this depends entirely on the climatic conditions of the range In some parts of Arizona and California it may start in February, whereas in Montana, North Dakota and South Dakota the shearing is in full swing by June The shearing plants are located at favorable points on the range where the bands have feed and water near-by This plant may be a temporary or permanent setup The shearing is done generally by traveling bands of shearers with machines The shearing crews usually shear about one or two bands a day. Early in the morning the band is brought to the shearing shed where the lambs are separated from the ewes which are then held in lanes back in the shearing corral awaiting their turn Each shearer draws his animal from the individual pen, which the wranglers have to keep full Right after the shearing each animal is freshly branded and trenched, and then turned loose to be united again with the lamb. At the end of the day the entire band of 1200 ewes is sheared and again on the trail, making room for a fresh band in the morning

After the lambs have reached the proper market-weight, 70 pounds and up, they are ready to be shipped This is done often by trailing the entire band to the railroad, where the market lambs are cut out and loaded and the ewes returned to the range Where

good roads are available, the lambs are sorted at the range and hauled in large double-decked trucks to the railroad

Sheep Raising in Texas

Texas belongs to the southwestern area and is the leading state in total number of sheep as well as in wool production. The sheep industry in Texas is conducted in a manner somewhat intermediate between the western range and the eastern farm systems The reason for that is that there are no public domains and practically all the grazing land is in the hands of private live stock producers Many of the ranches have put up wolf-proof fences and the sheep are turned loose in these enclosures The principal sheep raising area is the Edwards Plateau, comprising some forty counties in the southwestern part of the state between the Pecos and Colorado Rivers The plateau covers an area of approximately 22,500,000 acres and is recognized as the center of the sheep- and Angora-goat-raising industries of Texas According to the 1935 agricultural census, each of the thirty-seven Texas counties in this area was credited with more than 50,000 sheep, or over 82 per cent of the 7,000,000 head accredited to the 254 counties of the state In the northern part of the area cattle predominate and only enough sheep are kept to graze the weeds and other feed that cattle will not touch. As the sheep do not displace any cattle, and, in fact, when properly run have a tendency to improve the cattle range, their inclusion increases the gross carrying capacity of these pastures To the south, as the grass is replaced by shrubs, sheep become more numerous and only enough cattle are run to utilize the grasses that the sheep do not consume On the more brushy ranges goats in turn predominate, while sheep are a secondary enterprise, there being only a few cattle

The fine-wool breeds, particularly the delaine merino and the Rambouillet, have been found best adopted to the climatic conditions prevailing in this area The annual rainfall amounts to about 25 inches in the Edwards Plateau area, which has an elevation averaging around 2000 feet The fine-wool breeds constitute approximately 90 per cent of the sheep population of Texas and of this 75 per cent is of Rambouillet stock The reason for the popularity of the Rambouillet is the weight advantage of the lambs at weaning time over lambs of straight merino breeding, and their ability to make more rapid gains The Rambouillet lambs range between 55 and 75 pounds in weight at weaning time

Probably 95 per cent of the sheep population of Texas is loose-grazed within wolf-proof pastures These sheep fences are similar to the Australian sheep fences and were first introduced in Texas ranches about 1910 The most popular type of outside fence construction used is a mesh wire from 48 to 50 inches in height, supplemented by one or two barbed wires at 3- to 4-inch intervals on top The inside or partition fences are of 36-inch mesh wire with three or more strands of barbed wire placed from 4- to 6-inch intervals above the mesh wire

The water supply is provided by wells and reservoirs These reservoirs built of rocks or concrete, have storage capacities ranging from a few to many thousands of gallons, and are generally distributed over most of the ranches The sheep seldom have to travel more than ½ to 2 miles for water

The phenomenal growth of the sheep industry in Texas has probably resulted from the advantages of loose-grazing, which are (1) reduced handling costs, (2) increased carrying capacity, (3) fewer communicable disease problems, (4) increased yield per fleece (clean basis), (5) lighter shrinking fleeces, and (6) a larger percentage of lambs and lambs which weigh heavier at weaning time

Contrary to popular opinion, sheep and cattle are successfully grazed on the same range in southwestern Texas It is necessary that a balanced system of stocking be practiced and overstocking of the range avoided The carrying capacity of a representative area of the Edwards Plateau country for year around grazing 640 acres, is approximately as follows · sheep 150 to 200 head, mature cattle 10 to 25 head, and Angora goats 50 to 75 head

Sheep Shearing

Shearing is, like lambing, strictly a season job. Sheep are generally shorn once a year The circle chart prepared by the United States Department of Agriculture (Fig. 24) illustrates in an excellent manner the wool-shearing months in the main wool-producing countries and the period of heaviest receipts at the central markets It can be seen from this chart that in the United States during five months of the year sheep are shorn in some section of the land In March shearing goes on in Arizona, California, and Nevada, in April in California, Nevada, Utah, and Wyoming, in May in California, Idaho, New Mexico, Oregon, Texas, and Wyoming, in June in California, Montana, North Dakota, South Dakota, Oregon, Utah, Washington, and Wyoming, ending up in the far northern section in

July. In the fleece-wool states of the eastern part of the country most shearing is done in the months of April, May, and June, depending on the climatic condition of the state Shearing is one of the hardest kinds of work and anybody who has ever watched shearers at work realize this But the sheep shearer is the highest paid wage earner of the western plains He earns from 12 to 15 cents per head, and since a good shearer can turn out from a 100 to 150 sheep a day his daily wage may run from $15 to $20

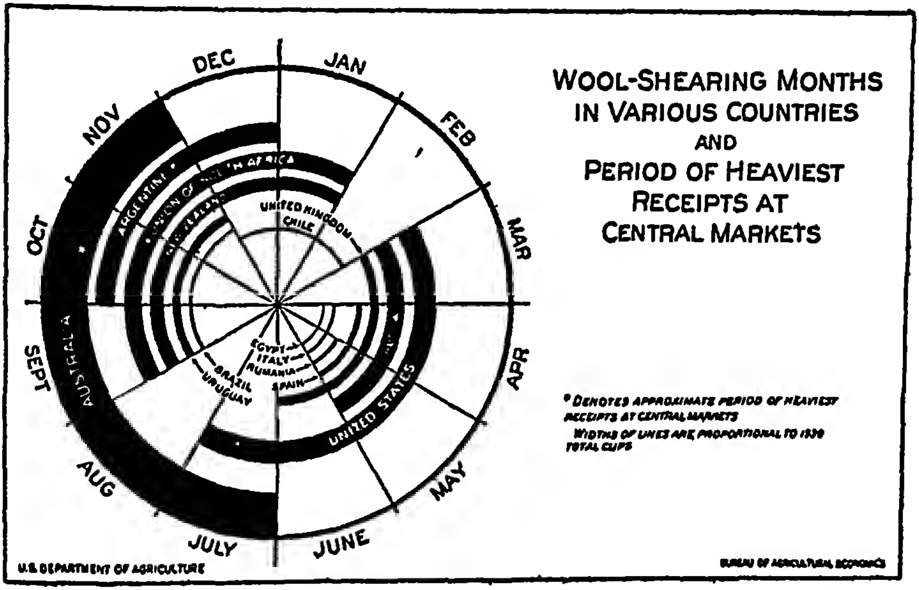


Fig 24

There are two kinds of shears in use, hand shears and machine shears The hand shearer, as the name indicates, shears directly by hand using a shears much like those used to trim hedges Machine men work with power shears run by gas engine or by electric motor or on small farms are hand-driven They operate exactly like the electric clipper of a barber The machine shearer does a faster job and the shorn sheep looks smoother than the hand-shorn animal It is claimed by many sheep men that the machine takes off too much of the wool, not leaving enough to keep the skin from being blistered or to prevent the animal from catching a severe cold should the weather change during the shearing period For this reason in Wyoming hand shearing is becoming more popular again

The shearing in the range states is generally practiced with machines by crews of shearers, which travel around from one ranch to another They carry with them portable gasoline engines, each furnishing power for two men On ranches with permanent shearing pens and where many bands of sheep have to be shorn, there is usually one large engine, steam driven, with a line shaft from which power pulleys go down to each pen

The present method of shearing was developed by the highly skilled shearer of Australia and adopted in this country in 1908 Today's scientific method of shearing is illustrated by Fig 25—"a motion picture of machine shearing"

The expert shearer, whether he uses the hand shears or the machine follows certain directions as the result of his long experience The Chicago Flexible Shaft Company directions are as follows:

1 Shear in a clean place on a smooth floor, platform, or large piece of heavy canvas

2 Never shear when the wool is damp or wet

3 If sheep are running on fresh pasture, hold them in the barn, on dry feed, the night before shearing

4 Take belly wool off separately

5 Shear in such a manner that the fleece is unbroken and with all the parts in their natural position, half on each side of the wool that grows along the backbone

It is possible with machine shears to shear the sheep on a bench, but it is easier, both on the sheep and on the shearer, to set the sheep directly on the floor When the sheep are sheared on the floor there is no unnecessary lifting Besides, the shearer's feet and legs can be used to hold the sheep in an easy, comfortable position Sheep seldom struggle while being sheared, if they are not crammed or twisted and held forcibly in such a position The U. S Department of Agriculture recommends the methods as illustrated

After the shearing is completed the next step is to roll and tie the fleece in a presentable way. Previous to the rolling careful sheep men will spread the fleece flesh side down and remove all dung and heavy sweat locks In rolling, the flesh side should always be outside as it presents a much brighter and more attractive appearance First the edges of the fleece are turned in, then the head and neck part The belly wool which was shorn separately is drawn in at the center The actual rolling is started at the bridge or tail and rolled towards the shoulder of the fleece This method will bring the shoulder and sides, or the best part of the fleece, into prominence.

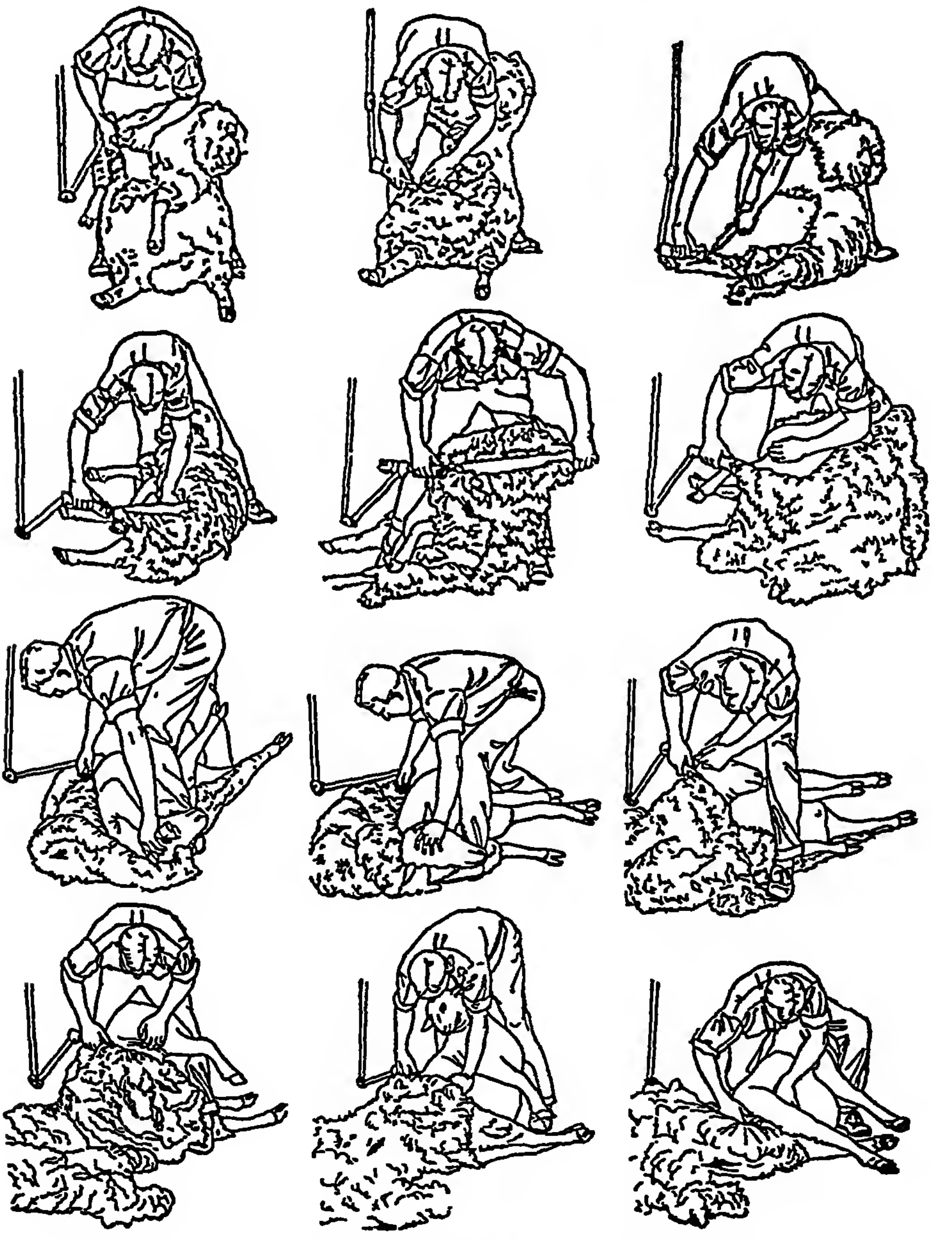


Fig 25 Method of shearing a sheep Read from top across.
Courtesy The Golden Hoof.

In the United States it is customary to tie the fleece with paper twines of 8½-foot lengths Jute or hemp twines are very objectionable The tieing is done by wrapping the twine once each way at right angles around the fleece On small farms the shearer does the tying, whereas on the western ranches a wool tyer is hired who does this work for the whole crew After the fleece is tied it is sacked directly in the bags for the market This work is done by a wool tramper, whose business it is to tramp the fleeces as solidly as possible into the 6-foot sacks that carry them to market The sacks are suspended free off the ground in a frame, and the wool tramper, starting at the bottom, rises as his sack fills This tramping is only customary in the United States, in Australia the fleeces are pressed into bales right at the shearing shed

Shearing of the Texas Wool Crop

In Texas between 15 and 25 per cent of the sheep are shorn twice a year, in the spring and in the fall. The spring shearing season begins in early April in the southern portion, being continued well into June before completion in the western and northern parts of the sheep-raising area The shearing is practically all done by Mexican crews, each of which operates under a *capitan* Fall shearing of sheep is at the present time an irregular practice and the number of fall-shorn sheep is influenced mainly by the condition of the flocks and the market prices of the clothing wools A nine-year study at the ranch experiment station located near Sonora to determine the differences obtained from shearing sheep once and twice a year resulted in the following data The average gain of fleece (grease weight) for the nine-year period was 0 8 pound for aged ewes and 0 7 pound for yearling ewes This gain in fleece-weights resulting in the twice-a-year shearing was, however, very often offset by wide and rapid fluctuation in wool prices (Fig. 26)

Docking and Castrating Lambs

Docking and castrating is mainly done to improve the appearance and value of the sheep They are considered among the necessary duties of a good shepherd, and are almost universally practiced in the large range flocks of the West

Docking is the removing of the tail, an operation best done when the lamb is between one or two weeks old Several reasons are offered in favor of docking The docked lambs are neater and the absence of the lamb's woolly tail enables the buyer to see the

Fig 26 Sheep shearing in Texas *Courtesy American Wool Council, Inc*

development of the leg of lamb. Docked lambs are cleaner, as long tails may gather dirt and filth and many become infested with wool maggots. Many different instruments such as knives, chisels, hot pincers or docking irons, hatchets or axes are used to dock the lambs. The average healing time needed after this operation is approximately three weeks.

Castration consists of removing both testicles of the lamb. Castrated lambs or wether lambs are preferred by the buyers and they outsell ram lambs by as much as one dollar per hundred pounds.

Sheep Branding

To distinguish the various sheep in each flock, most sheep raisers brand or mark the animals with tar, paint, or other identifying marks and stains to prevent confusion with sheep owned by other farmers. The manner of branding sheep is treated as a matter of no consequence by the great majority of sheep and wool owners. If they could realize the damage that is done to the machinery, yarns, and fabrics when tar is present in the fleece, they would try to improve their branding method and meet the wishes of the manufacturers.

A survey of the kinds of fluids used in branding sheep in various parts of the country is being made by the Bureau of Agricultural Economics in an effort to determine what fluids are most suitable for branding purposes. Manufacturers who use the bulk of the domestic clip have reported to the Bureau that despite every known precaution taken by them, the damage from the use by wool growers of insoluble fluids as a branding substance cannot be fully eliminated under present conditions. Investigations by the Bureau's Wool Section tend to substantiate this claim.

Each staple having dried branding material must be clipped by hand. The encrusted clips are known commercially as "paint clips" and sell for very little. These "paint clips" undergo a process of depainting in which a special solvent treatment is used, after which the clips are used in very cheap fabrics. It has been estimated that an average of about thirty minutes per bag is used up in clipping the brand marks from fleeces at the time of sorting. One man will probably sort five bags of wool per day, which means, figuring conservatively, that over two hours time per day for each sorter may be charged directly to the necessity of clipping brand marks by hand. Wool sorters are among the highest paid of the textile workers.

ing a careful check to determine just what branding fluids are now being used by the growers Information will be gathered concerning the composition of the fluids and their costs to the sheep owners since any fluid, to be widely used, must be made available to the growers at a reasonable cost

Selected fluids which are or could be made available to the growers at a reasonable cost, should be tested thoroughly to determine those best suited to all branches of the industry Any improvement that may tend to reduce the conversion cost of domestic wool should be reflected in the returns received by the growers

Parasitic Sheep Diseases

Sheep probably suffer more from internal and external animal parasites than any other kind of livestock, although ordinarily they are not subject to diseases caused by bacteria and viruses Most losses occur among lambs, as the young animals are usually more heavily parasitized and appear to be more seriously injured by a given infestation than are the older animals

Parasites and disease are responsible more than anything else for keeping sheep growers in the red It is because of such hazards that more farmers do not raise sheep This, however, is not the place to discuss in detail the most common parasites and diseases which affect sheep A flock owner can do much to prevent such losses by:

1 Rotating pastures
2 Dipping every year for skin parasites
3 Treating regularly for worms

4 Furnishing clean, dry, well-ventilated quarters, especially during lambing.

5 Furnishing proper feeds and clean water

6 Starting with and adding only healthy sheep to the flock.

The combating of internal and external parasites is perhaps the greatest problem the farm flock producer has to face. The internal parasites are best fought by giving the animal a strong internal antiseptic such as a solution of copper sulphate and nicotine sulphate at monthly intervals during the grazing season This treatment is known as "drenching," and the solution as "the drench"

The best means of combating such external parasites as ticks or lice is to dip the sheep in special dipping vats The flocks are normally dipped once a year, the best time being in the spring when the wool has from one month to six weeks' growth The solution is a strong antiseptic, arsenical dips also have proven satisfactory

Anthrax

One disease which must be mentioned as not only dangerous to sheep but which also may infect the workers who are handling the wool of infected animals, is anthrax or wool sorter's disease Anthrax is a rapidly fatal, infectious, febrile disease In sheep it usually takes the acute form, but it is sometimes subacute only

The disease is caused by the Bacillus anthracis, an organism of microscopic size. Anthrax is contracted through wounds exposed to infected soil, and through the contamination of wounds by flies which have fed on carcasses of animals that have died of anthrax or on discharges from diseased animals

In sheep the disease usually runs a rapid course, especially in the first animals affected Apparently healthy animals suddenly develop weakness of the legs and difficult breathing. They fall to the ground, move convulsively, and may die in a few minutes or within an hour Where death is less sudden, periods of stupor alternate with convulsions, the mucous membranes of the nostrils and mouth become bluish, the temperature is highly elevated, and bloody discharges may issue from the mouth, nostrils, or anus

Each year in various parts of the world thousands of sheep and cattle and many human beings perish from the ravages of anthrax In the United States annually about 120 people are afflicted with the malady—probably a small number when compared with world totals but far too great when one considers that the cases are largely confined to workers in the wool and the tanning industries—and the carpet industry in particular. In the belief that an occupational

disease, so narrowly restricted, can to a considerable extent be prevented, Dr Macdonald has studied anthrax in the pathological laboratory of Cornwall Hospital, Cornwall, N Y., and reports his findings and recommendations as follows.

"Wool workers who handle imported wool or hides are constantly exposed to anthrax, an infectious disease, which may attack the skin, lungs, or intestines. One form is known as 'wool sorter's disease' The most common form of the malady appears as a lesion in the skin not unlike the common 'boil,' except that it is practically insensitive and has a tough black center, often surrounded by a circular row of silvery beadlike points of skin elevated by underlying fluid This form is the result of anthrax bacilli entering the skin through a cut, abrasion, or infection Forms commencing in the lungs or intestines, from breathing or swallowing the germ, are practically unknown in the United States.

"Workers in wool-carpet mills probably are exposed to anthrax more continually than other wool workers, since most of the wool which goes into American carpets is imported from Asiatic and tropical countries where the disease is prevalent This, however, does not mean that all other wools are free from bacilli

"The formaldehyde sterilization process, as practiced in England, where all goat hairs and known dangerous wools are disinfected compulsorily at the port of entry under government supervision, has been found effective in dealing with the most heavily infected wools"

Still another method of sterilizing wool, when it is loosely packed, is to apply live steam under a few pounds pressure for fifteen minutes However, the difficulty and cost of such treatment of large lots of wool in the average mill are obvious Although the formaldehyde treatment renders the product practically sterile, and although the described investigations prove that the majority of wool workers are protected automatically, a considerable percentage of workers are left open to infection during the early operations To date, short of expensive methods of wholesale sterilization of raw wool, nothing but precautionary measures against infection can be instituted. However, if certain precautions are taken seriously (with enforced co-operation of employees), there should be only rare cases of anthrax—and these should be detected early and treated effectively

Chapter 3

THE PHYSICAL PROPERTIES OF WOOL

THE WOOL FIBER

WOOL is an animal fiber forming the protective covering of sheep As a product of the skin or cuticle of vertebrate animals, it is similar in origin and general composition to the various other skin tissues found in animals, such as horn, nails, and hoofs Wool is an organized structure, growing from the root situated in the dermis or middle layer of the skin The purpose of the hair covering is to keep the body temperature of the animal normal The wool fibers are poor conductors of heat and, therefore, prevent abnormal temperature changes in the body At the same time, the air between the fibers is uniform in temperature, which adds to the protection against sudden changes The fleece works as a sense organ because of its contact with the nervous system of the skin

Structure of the Skin

The animal skin consists of two distinct layers—the epidermis or horny layer and the dermis or fine skin Each of these two layers is subdivided into several parts The skin ranges in thickness from 1/32 to 1/8 in Cells in the epidermis of the embryo animal grow down into the dermis and form a sheath in which the hair starts its growth (Fig 1). The root of the wool fiber, which is termed the hair follicle, is a gland from which, through the secretion of a lymph-like liquid, the various cells forming the hair are developed The hair follicle also secretes an oil which is supplied to the fiber during its growth and serves as a lubricant for its several parts, giving it pliability and elasticity

Surrounding the hair follicle are two kinds of important glands —the suint glands and the sebaceous glands. The suint glands

[1] This chapter is largely taken from J Merritt Matthews and H R Mauersberger, *The Textile Fibers*, 5th Edition, by permission of the publishers, John Wiley & Sons, Inc., New York, 1947.

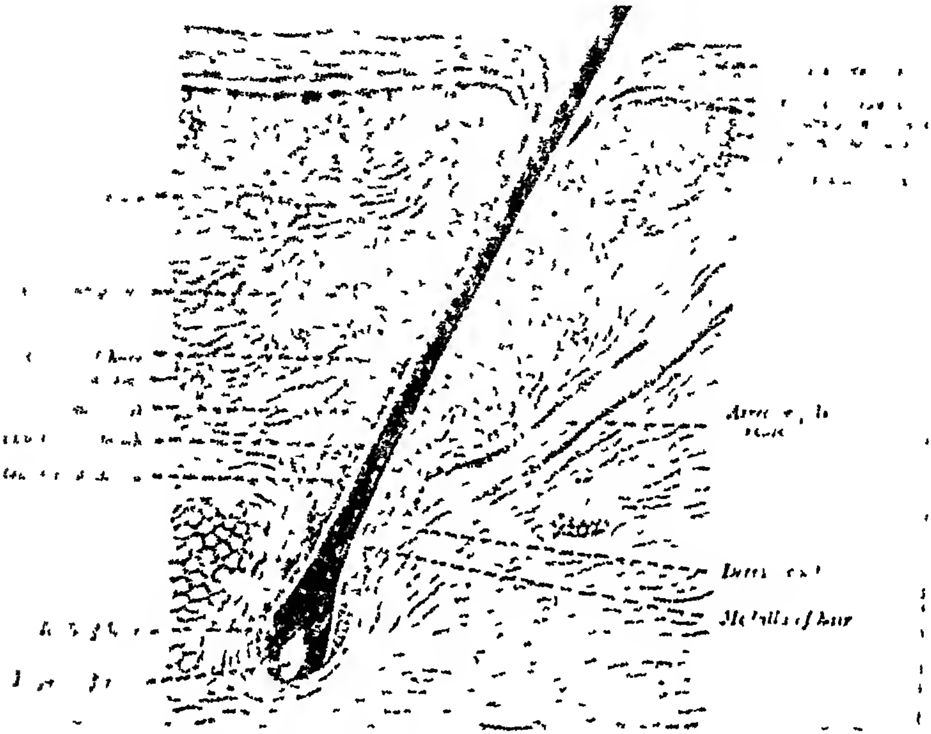
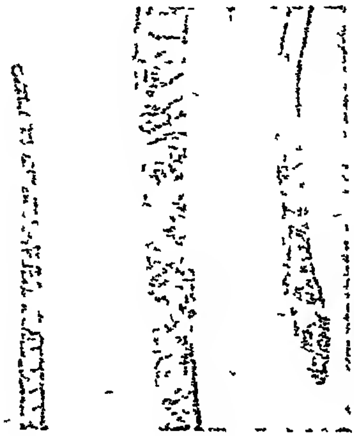


Fig 1. Diagram of skin structure in region of a hair (*Gray's Anatomy*)

secrete potash salts of various fatty acids, which prevent the hair from being damaged by the chemical influence of sunlight The sebaceous glands secrete the wool fat, which forms a protective coating on the surface of the wool fiber and preserves it from mechanical injury during its growth. At the same time it prevents the fiber from becoming matted or felted together, and also acts as a water repellent or raincoat

The full-grown hair as a whole consists of two parts—the root, or the part which is in the skin, and the stem, or shaft, which is above the skin. The root is fixed at the base of the sheath and when the hair is pulled out, part of the hair follicle comes with it, having a form as shown in Fig 2 The stem is generally cylindrical and is tapered to a point at its free end On cutting, the fiber acquires a flat end which it will never lose since growth occurs from the root end. The tapering ends are characteristic of lamb's wool, whereas the cut ends indicate that the animal has been previously shorn. (Fig 3.)



A B C

Fig 2. Parts of a merino wool fiber.

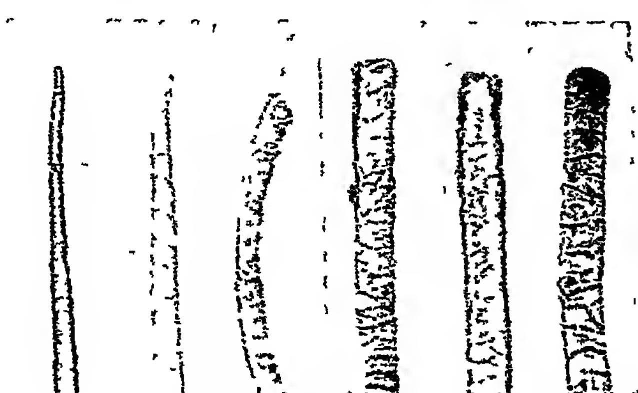
A—tip; B—stem; C—root (X500) (*von Bergen*)

Growth and Fleece Density

Wool hairs grow in groups of five to twelve hairs. The groups are so arranged in the skin that they form horizontal lines. The arrangement is governed by a definite law. In each group is present a leading hair, which is recognized by its position between the oil and sweat glands. This main hair differs in no way from the others in size or structure. The density of the hair over the entire body of a sheep varies according to the breed as well as varying with each individual fleece. Fleece density is one of the primary factors in wool production, as it has a direct relationship to the amount of wool obtained.

Considerable variations of fleece density are found in the different breeds, and no classification can be made because certain breeds overlap others. Burns found that the number of fibers may vary in the different parts of the body from 10,000 to 22,000 per sq. in. of skin.

In Burns's review of the published work on fleece density, various research workers gave the data on the number of fibers per square inch of skin shown in Table 1.



Left | Right

Fig 3. Various forms of fiber tips.

Left—Tips of lambs' wool. (X500)

Right—Tips of shorn wool. (X250) (*von Bergen*)

TABLE I

FLEECE DENSITIES BY BREEDS

Breeds	*Number of Fibers per Square Inch of Skin*
Hampshire	8,000 to 25,000
Hampshire Rambouillet (crossbred)	12,000 to 34,000
Rambouillet	17,000 to 56,000
American Rambouillet rams (four animals)	33,000
Australian merino rams (two animals)	61,000
American merino, type B	16,000 to 23,000
Tasmanian merino	27,000 to 40,000
South African merino	35,000 to 60,000

Fig 4 Vertical cut through skin showing various fiber groups and glands (X110) (*Summerill*)

Assuming that a sheep has a skin containing 12 square feet and that the fiber has grown fairly uniformly on the skin of different parts of the body, the total number of fibers grown on the sheep may be calculated The Hampshire has from 16,000,000 to 43,000,-

000 fibers, the Hampshire Rambouillet has 21,000,000 to 59,000,-000 fibers, the Rambouillet has 29,000,000 to 97,000,000 fibers; and the Australian merino grows up to 120,000,000 fibers.

There is a considerable drain on the body of the sheep when nourishing from 16,000,000 to 100,000,000 or more fibers, all growing uniformly at the rate of about ½ inch per month. Spoettel and Taenzer estimated the number of fibers over the whole carcass of the merino lamb as 20,000,000 and a full-grown merino 126,-000,000 fibers.

Change of Hair

The ancestor of the domestic sheep lost its entire body covering each spring The covering of the wild sheep is very different from that of domesticated sheep. It consists of two distinct coats—the outer of long fibers and the inner of short fibers. The long fibers are medullated, brittle and very coarse, the short fibers are elastic, fine, and wavy. This wooly undercoat in the course of evolution and through very careful breeding, has developed considerably, and it now represents the main covering of domestic sheep. The wool of domestic sheep grows continuously and, if not shorn or if protected or prevented from breaking off at the tip, it may attain a length several times its annual growth.

This annual shedding or molting process still occurs in certain breeds yielding mixed wool, such as wild sheep like the Rocky Mountain sheep, and hair-carrying animals, such as goats and camels, yielding fibers closely related to wool.

Wool, Hair, and Kemp

Wild sheep carry two distinct coats, the outer of which consists of long fibers that are classified as hair; if they are especially coarse, brittle, and strongly medullated, they are known as kemp. The undercoat consists of fine, crimpy fibers called wool. (See Fig 5.) Unfortunately, up to the present time breeding has not entirely banished the coarse fiber, for it is still evident in all breeds of sheep except the merino, where it has disappeared. In medium and long-wool-type breeds, the kemp and hairy fibers are noticeable on the head, legs, and britch, though the proportion in the numerous breeds varies considerably. In the mixed wools, such as Scotch blackface, Welsh wool, or carpet wools in general, the entire fleece is a mixture of all three. (See Fig. 6.)

The undercoat consists of fine, crimpy fibers, whereas the outer coat is formed by long, coarse, wavy hairs. Both coats are intermingled with short, coarse kemp fibers. By careful examination even fibers will be found which have the characteristics of both wool and hair, that is, they may have certain parts that are perfectly fine and that possess all the characteristics of true wool and other parts that present very hairy characteristics. They are known as heterotype fibers. The hair portion is, as a rule, strongly medullated and is generally found at the tip of the fiber. In other fibers the base may be medullated and the distal portion fine, or the tip and the base may be medullated and the central portion fine.

Fig 5 Crossbred wool showing uniformity in fineness (X8) (*Krauss*)

Fig 6 Carpet wool showing wool, hair and kemp Great variation in fineness (X8) (*Krauss*)

Northcroft found the following type of fibers in adult staples of New Zealand wools:

1. *True wool.* (*a*) Fibers running throughout the length of the staple. (*b*) Fibers at the base of the staple and running only for a short distance. (*c*) Fibers which have been shed and appear anywhere in the staple These may sometimes be much longer than (*a*) and lower ends are frequently found at the same level in the staple and so form a distinct zone—the cotted zone This necessarily varies considerably in degree of cotting, and can become a dense tangled mat

2 *Heterotype fibers* (*a*) Growing fibers running throughout the length of the staple (*b*) Shed heterotypes, which as a rule are found

toward the ends of the staple, the proximal end being found in the cotted zone.

3. *Kemp* Fibers shed from the follicle. They are short, wavy, tapering toward each end, dead white or opaque, with a large amount of medulla, and are very coarse and brittle (Fig 7)

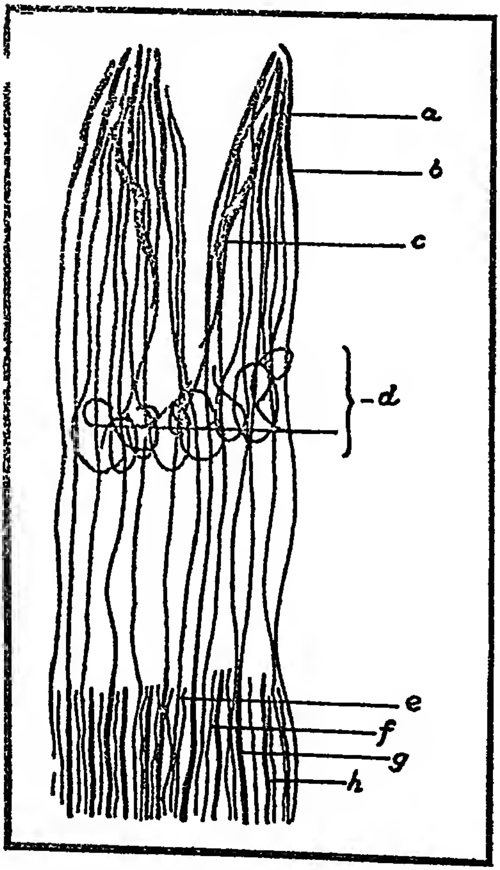


Fig 7.

Possible types of fibers present in a wool staple *a*, hetero-type fiber thickened at tip *a* and base *g*, *b*, hetero-type fiber thickened only at tip, *c*, kemp fiber; *d*, cotted zone; *e*, true wool fiber, *f*, developing fiber, *h*, developing medullated fiber which may result in a hetero-type of the *a* or *b* class or in *c*, the kemp fiber (*Northcroft*)

Northcroft in his further study of New Zealand wool fibers explains the foundation of the various fiber types as follows

From the point of view of evolution, the true wool fiber is clearly the component of the old inner fine-wooled coat of the wild sheep It has been developed at the expense of the outer or kemp coat, which has, in the domestic sheep, dwindled down to a few scattered fibers in the adult and is strongly represented only in the first coat of some lambs

In the fleece of the wild sheep there are no heterotype fibers, and it is not clear how they originated May it not be that they are a result of suddenly changed conditions in the life of the individual? The heterotype fiber most commonly found is that with a thickened tip and with a great part of the fiber a pure-wool fiber The thickened part is, of course, the part that was first formed after shearing. The sudden need for a covering, and perhaps a sudden stimulus to fiber growth, was responded to by a production of fibers many of which had the character that preponderated in the coat of the ancestral forms When a sufficient growth had taken place many of the follicles that had thus responded by forming coarse fibers resumed their more

modern function of forming wool They may have formed kemp because that constituted the best form of protective covering, but it is more likely that it was because the forming of this type of fiber was a function older in time and therefore one to which they naturally reverted when a sudden call was made upon them If a wattle-tree that normally produces only phyllodes in the adult condition is cut back it produces leaves such as it produced in its first year, or such as its ancestors produced The view here put forward as to the origin of thickened tip is rendered the more probable, seeing that it is more common in rigorous climates Further, where tip and base are both thickened, it may be that adverse conditions have occurred twice in the year.

From the foregoing it seems evident that there is no distinct dividing line between true wool and true hair fibers.

Histology of Wool Fiber

The minute structure and external shape of the wool fibers were established by the classic researches of Nathusius in 1864, in Germany In the United States the classic work in establishing the physical properties of American wools was done by W. McMurtrie, Professor of Chemistry at the University of Illinois, 1880-86. McMurtrie's work was provided for by an Act of Congress (approved June 16, 1880) for the examination of wools and other animal fibers by the Department of Agriculture under the following terms

> For testing, by scientific examination, the tensile strength, felting capacity, and other peculiarities of the different wools and other animal fibers on exhibition at the International Sheep and Wool Exhibition to be held in Philadelphia in 1880, four thousand dollars

The report, which was published by the Department of Agriculture in 1886, is a volume containing more than 600 pages, it had an edition of 10,000.

The latest information concerning the fine details of the structure of wool fibers was published by Hock, Ramsey, and Harris A growing fiber consists of a root and shaft, the root is the living part situated beneath the surface of the skin, whereas the shaft is the nonliving part that extends above the surface of the skin The root has a scallionlike shape The shaft is cylindrical and tapers to a point at its free end, provided the fiber has not been cut previously Since the cells of the root are alive and growing, whereas the cells of the shaft are dead, there exist profound physical and chemical differences between these two parts of the fiber Several of these differences can be revealed by microchemical color tests The differences established between the root and shaft are given in Table 2

TABLE 2

DIFFERENCES BETWEEN ROOT AND SHAFT OF WOOL

Root	*Shaft*
Soft and easily crushed	Tough and horny
Cells roundish	Cells elongated.
Positive test for nucleic acid	Negative test for nucleic acid.
Nuclei stained with hematoxylin	Nuclei unstained with hematoxylin.
Cytoplasm granular in appearance	Cells distinctly fibrous.
Not birefringent	Birefringent
Positive test for sulfhydryl groups	Negative test for sulfhydryl groups
No Allwoerden reaction with chlorine water	Many large Allwoerden "sacs."

Increase in fiber length is brought about by the proliferation of new cells in the root and the subsequent pushing-upward of these cells into the shaft, which is composed of dead cellular units During this process a transformation of the cells takes place which results in the formation of two or three distinct layers—the epidermis, an outer layer of scales, a middle region called the cortex, and a central core or medulla The two-layer shaft is generally characteristic of true wools, the three-layer shaft of coarse wool and hairs (Fig 8).

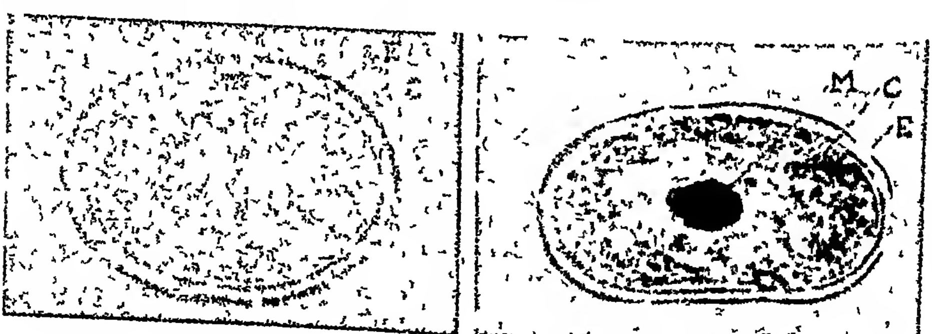


Fig 8 Cross Section of two hairs (X360)
E—Epidermis, C—Cortex, M—Medulla

The Epidermis or Cuticle

The outside or surface of the fiber is made up of flat irregular horny cells or scales They overlap like the shingles of a roof with the free end projecting outward and pointing toward the tip of the

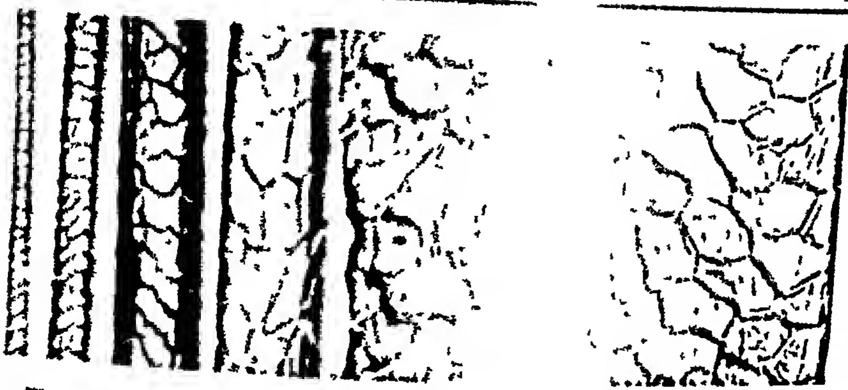


Fig 9 Various types of scale ... fibers (X250)
(...)

hair, causing the surface of the ... present a "serrated" appearance.

Depending on the diameter of the ..., the number of scales necessary to cover the circumference of the fiber varies considerably. The average height of the scales is approximately 28 microns and the average width approximately 36 microns. The thickness varies between 0.5 and 1 micron. In the finest wools each one of the scales is large enough to encircle the shaft of the fiber, giving the impression of flower pots set into each other. (See Figs 9 and 10.)

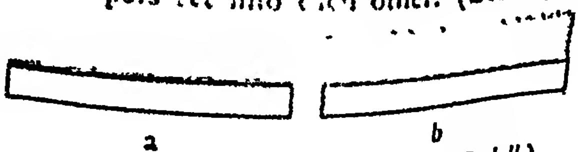
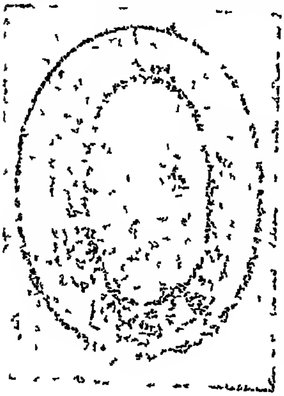


Fig. 10 Diagrams of scale patterns (Rudall)

With increased fiber diameter the number of scales necessary to cover the circumference increases proportionally. Except for a few indistinct markings on the surface, individual scales show little evidence of internal structure. The scales are arranged either shinglelike, overlapping longitudinally and circumferentially or in a manner whereby the surface of the fiber is given a tilelike appearance. These different types may be found in the same hair ...

The visible scale height is an important characteristic for differentiation between wool and related hair fibers, such as mohair and camel hair. In fine wools these visible scale lengths are 8 to 10 microns. In coarse wool, the scale length may increase to 18 microns. This decreases the overlapping of the scales and gives the entire fiber a smoother appearance. As the ... of the scales ...

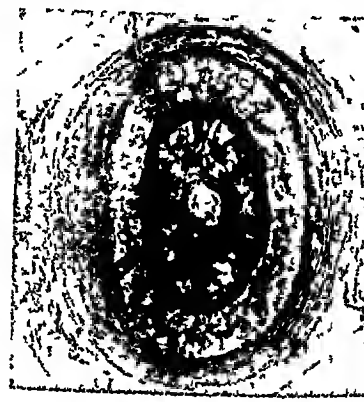


a

Fig 11 Cross sections of guard hairs from a kolinsky fur pelt.

a) Maximum thickness of epidermis about 7 microns (X750)

b) Swollen with sodium hypochlorite Epidermis separated into a series of flattened, plate-like cells (X500) (*Rudall*)



b

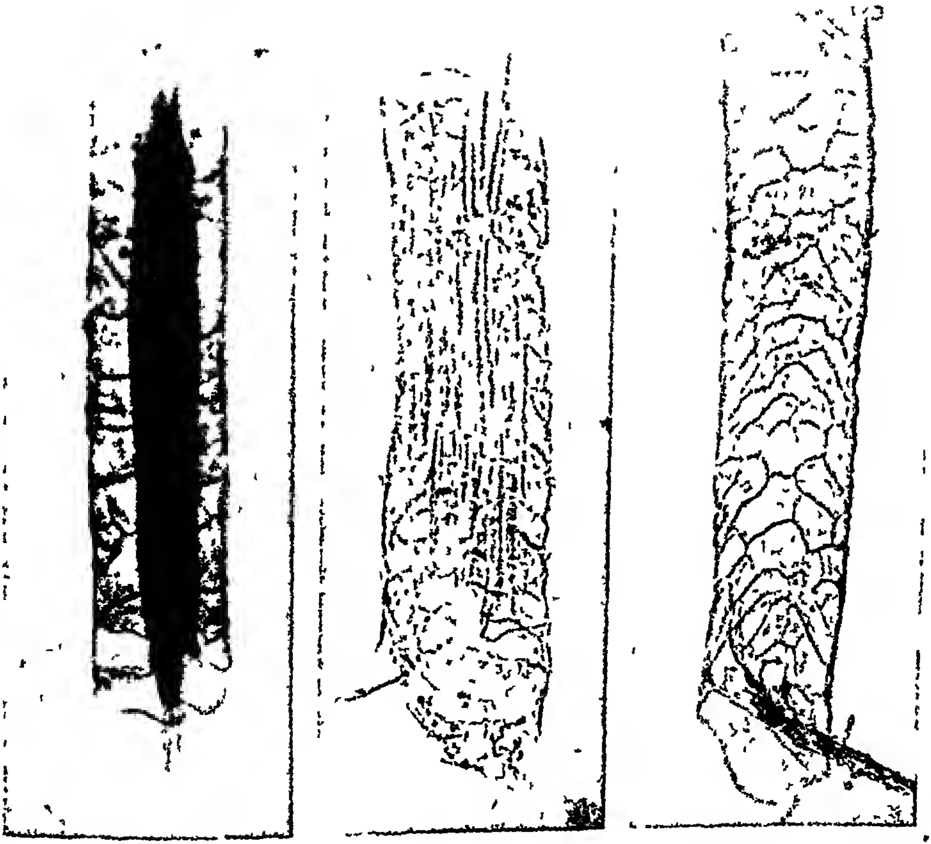
over each joining scale very closely, coarse wool is usually more hairlike and lustrous in texture. The number of scales per 100 microns (or 1/253 inch), when counted along the edge of the fibers, averages ten or twelve but may range from six to fourteen.

The thickness of the epidermis varies considerably with different animal fibers Whereas in wool the thickness is between 0.5 and 1 micron or about equal to the thickness of one individual scale, in human hair (3 microns) and in some fur fibers (kolinsky fur, 7 microns) the peripheral layer is greatly thickened Rudall, by observing the swelling of fiber sections in sodium hypochlorite solution, came to the conclusion that the thickness of the epidermis is a function of the length of the cuticle cell and the degree of overlap of these cells

In fibers such as wool, the scale cells are arranged as in Fig 10*a* Thus, the thickness of the epidermis is from one to two times the thickness of the individual cell In fibers such as guard hairs (distal region) of ermines and martens the epidermis is of the type shown in Fig 10*b*

In the kolinsky fur fiber where the epidermis measured 7 microns by swelling with sodium hypochlorite, the layer separated clearly into at least 18 layers of flattened platelike cells (See Fig 11*a* and Fig. 11*b*.)

Hock demonstrated excellently that the epidermis scales surround the main layer of the wool fiber in a tubelike fashion In following microscopically the changes which chemically altered wool undergoes in pepsin, he found that the scales remained attached to each other in the form of tubes (Fig 12) Cuticle scales are not fibrous and the lack of fibrillar structure was further confirmed with the



A B C

Fig 12 Reduced and methylated wool fibers treated with solutions of pepsin A, B and C show three stages in the removal of cortical cells from the fibers A and B unstained, C stained with Orange II (X350).
(*Hock, Ramsay and Harris*)

the whole fiber, and suggests a more or less random orientation in the cuticle

The Cortical Layer

The cortex is found below the protective epidermis scales. It constitutes the principal body of the wool fiber and is made up of long, slightly flattened and more or less twisted, spindle-shaped cells The average cells range from 80 to 110 microns in length, 2 to 5 microns in width, and 1.2 to 2 6 microns in thickness (Fig 13)

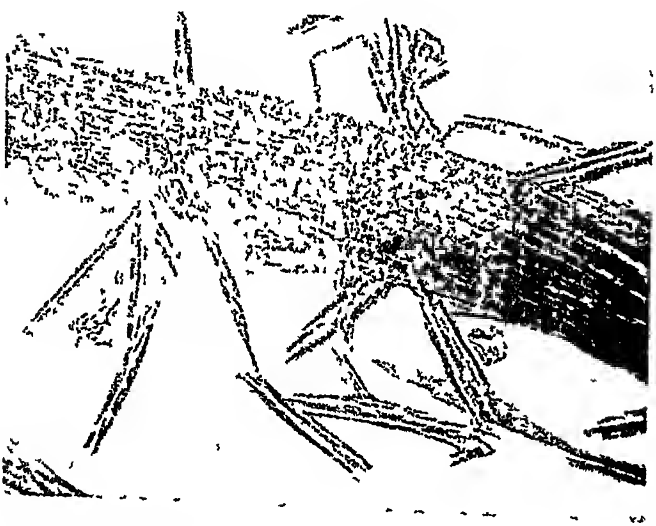


Fig 13 Wool fiber showing arrangement of cortical cells (X500)

Individual cortical cells liberated from the fibers by chemical agents are in most cases prominently striated, showing fibrillated ends. The striated appearance of these cells is owing to the presence of many fibrils. Near the center of each cell is a nucleus which has a granular structure Between crossed nicols the fibrillar part of the cortical cells appears birefringent whereas the nucleus does not Nuclei are not easily observed in the untreated cross section but are clearly visible after they have been properly stained or swollen (Figs. 14 and 15).

The cornified cortical cells are rather closely packed and because of their length give the effect of longitudinal striations, which are more or less visible through the epidermis The forces holding the cells together are not yet properly known According to Frolich, there is a liquid present between the plasmatic cells as they exist in the root of the fiber In the process of growth these cells change from a globule into the long flattened shape with progressive cornification and contraction The liquid present between the original cells may act as a cementing fluid. Rudall states:

A B C

Fig 14 Single cortical cells from reduced and methylated fibers photographed under various conditions. A—cell, stained with Orange II, showing the nucleus and the fibrillate appearance of the rest of the cell. B—cell, between crossed nicols, showing the non-birefringent nucleus in the birefringent cell C—single cell nearly eaten in two by the prolonged action of pepsin (X 1400).
(*Hock, Ramsay and Harris*)

Cortex and cuticle are produced simultaneously from neighboring undifferentiated cells in the follicle bulb Outer cells are modified to form the cuticle and the inner cells form the cortex and also the medulla, if this is present. These changes express either primary differences in the cell, such as differences in the synthesis of the cell proteins, or secondary differences in that the same protein molecule is brought to its particular final state by different conditions of denaturation or by the action of agents, such as tan molecules.

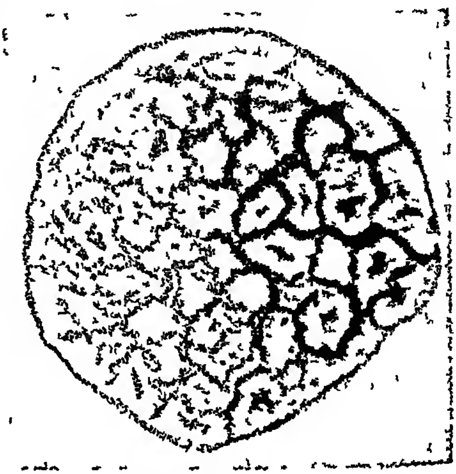


Fig 15 Cross-section of a wool fiber after several weeks in a solution of pepsin followed by swelling with 9 per cent sodium carbonate. The photomicrograph shows the outline of the individual cortical cells and their nuclei. (X1500) (*Hock, Ramsay and Harris.*)

The tensile strength and the elasticity of any hair is owing chiefly to the cortical layer of the fiber Any separation of the cortical cells through mechanical action, such as bending, or chemical action by strong acids will result in the loss of strength In natural colored fibers, such as brown and black wool, the cells are filled with colored pigments in varying degrees. Between the cells cigar-shaped air pockets or vacuoles may be present.

The examination of cortical cells with the electron microscope by Hock and McMurdie confirmed and extended the results obtained with the ordinary microscope. Whereas only fibrils were observed with the optical microscope, the electron microscope resolved still finer filaments called microfibrils Figure 16 represents part of a cortical cell at a magnification of 36,000 The microfibrils like the fibrils do not appear to be constant in width but vary from a few hundred to 1000 Angstrom units.

The Medulla

In medium and coarse wools, a third layer is found within the cortical layer, a cellular marrow or medulla In the fine merino wools medullated fibers are present to the extent of 1 to 1000 The medulla is built up of many superimposed cells, of various shapes, often polygonal, forming a honeycomblike structure.

The diameter of the cells varies from 1 to 7 microns Various porous channels pass through the medulla cells, which are normally filled

Fig 16 Part of a cortical cell showing its fibrillate structure (Electron micrograph X 36,000) (*Hock and McMurdie*)

C
Fragmental

B
Interrupted

A
Continuous

Fig 17. Types of medullas in wool fibers (X 250)

with air. The shape and size of the medulla vary greatly The medulla might consist of a single chain of cells or of several series arranged side by side, it varies from 10 per cent to over 90 per cent of the whole fiber According to their arrangement, medullas are classified in four groups (1) the fragmental, (2) the interrupted, (3) the continuous, and (4) the discontinuous In true wool only the first three are found (Fig 17) The discontinuous medulla is characteristic of fur fibers such as rabbit hair.

The presence of medullated fibers in any wool is detrimental to quality from the standpoint of the manufacturer They are defective because of their hair character—straight, coarse, and lustrous The spinning properties are lower, and in piece-dyed fabrics

they produce a "skittery" or heathery effect by dyeing a lighter shade. The medulla is in no way necessary for the growth of the fiber; its main function is to increase the protective properties of the fiber by adding internal air spaces.

Further experiments were made by Rudall on New Zealand Romney lamb's wool to study the causes of medullar production. The result of his experiments proved conclusively that the medulla-producing effect often found after shearing is due to exposure and not to the mechanical effect of shearing. In Table 3 are given the results of some of the tests, showing the medulla-producing activity in follicles from the shorn and unshorn sides of differentially shorn lambs. A well-marked increase in the number of follicles producing a continuous medulla is shown in each case

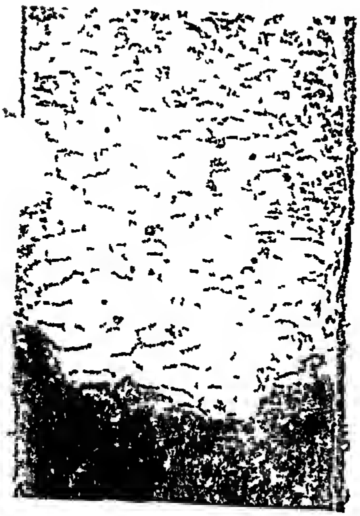
TABLE 3
VARIATION IN NUMBER OF MEDULLATED FIBERS DUE TO EXPOSURE

Animals	*No of Follicles*	*Continuous Medulla* (1)	*Discontinuous Medulla* (½)	*No Medulla* (0)	*Total Medulla as a Per Cent*
Unshorn side	104	0	9	95	4 5
Shorn side	104	10	26	68	22
Unshorn side	104	5	66	33	35 6
Shorn side	102	47	26	29	59
Unshorn side	101	21	15	65	28
Shorn side	98	58	20	20	69 5
Unshorn side	103	0	11	92	5
Shorn side	104	60	24	20	69

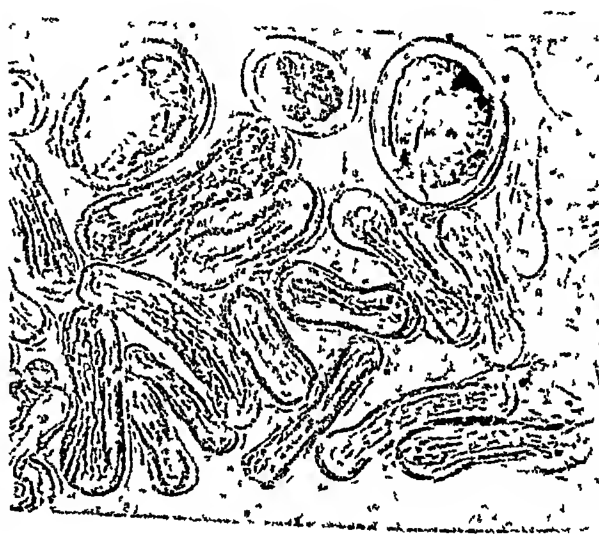
Kemp Hair

Kemp fibers are mainly present in mixed wools such as carpet wools. Their presence is always a sign of poor breeding. They are easily recognized with the naked eye. They are normally short, wavy, and tapering toward each end, are of a dead-white or opaque color, and are very coarse and brittle. They shed naturally from the skin after several months of growth and are found mostly in the upper part of the staple. They are especially present in fleeces of lambs which are born with comparatively few medullated fibers, but which after birth develop an outer coat of medullated, coarse

kemp fibers Microscopically these kemp fibers are strongly medullated, smooth, and tapering at each end The medulla usually starts a short distance above the hair bulb and at its greatest diameter may form 90 per cent or more of the fiber. Toward the tips, the medulla commences to taper again to a point, it then becomes interrupted, and finally disappears, leaving the tip entirely free. The kemp cross section is generally ribbonlike, as seen in the photomicrograph (Fig. 18).



a



b

Fig 18 Longitudinal and cross section of kemp hairs (a) Kemp hair nearly 100 per cent medulla. In black part of fiber medulla cells are filled with air (X 120) (b) Cross section of kemp hairs showing their various forms, circular and ribbonlike The black parts in the medulla are air-filled cells. (X 250)

X-Ray Analysis of Wool Fiber

The technique of x-ray analysis has found an important place in disclosing the submicroscopic structure of the wool fiber. The work of Astbury is outstanding in this field.

Hair and wool protein (keratin) has a large capacity to stretch and great elasticity which distinguishes it sharply from silk fibroin. Unstretched human hair, wool, fur, and also horn, nails, spines, and whalebone all give the same x-ray photograph, but when stretched they give another kind of pattern Mammalian hairs differ in this respect from fibers of cellulose and natural silk. When cellulose or natural silk is stretched the x-ray photograph remains unchanged,

except for orientation effects, whereas the mammalian hairs show long-range reversible elasticity, when released in water they recover their original length exactly.

X-rays show that the wool fiber is built up of crystals which are far too small to be seen with the aid of visible light. They exist in certain shapes and sizes and lie in certain directions in the fibers As far as is known keratin exists in three forms The x-ray shows definite existence of two of these: the unstretched form, α-keratin, built from folded polypeptide chains and the stretched form, β-keratin (Fig. 19), built from the same chains pulled out straight. The third is the "super-contracted" form, assumed after the fiber has been stretched and treated with heat and moisture for a short time. If it is allowed to contract, it will contract to a shorter length than the α-form. The x-ray pattern does not reveal any new definite repeating pattern for this form. The two x-ray photographs show the characteristic molecular pattern of an unstretched and stretched wool fiber. In Fig. 19 of Cotswold wool, stretched 90 per cent of its initial length, there is a remarkable contrast to the unstretched fiber. So long as hot water is avoided, the intramolecular transformation from α- to β-keratin and back again, with corresponding changes in the x-ray photographs, may be repeated as often as desired.

Unstretched wool fiber (α keratin) Fig 19 (Astbury) Stretched wool fiber. (β keratin)

Astbury and his co-workers have already explained much hitherto unknown detail of the nature and structure of wool and its response to many manufacturing processes, and their work has been further enlarged by Wrinch, Neurath, Pauling, and Niemann

QUALITY CHARACTERISTICS OF WOOL

In estimating the value and suitability of wools there are several characteristics which are important in determining the quality. First and foremost of these is fiber diameter or fineness. The length, the amount of impurities or shrinkage value, strength, color, luster, and vegetable matter content are also significant. In all these properties the wool fiber varies within wide limits, depending on the breed and geographic location of the sheep and the part of the fleece from which the wool is derived

Conversion of fibers into yarns and goods brings out additional physical characteristics, such as the contour, crimp, elasticity, resilience, rigidity, felting quality, specific gravity, moisture content, electric properties, and warmth (heat conductivity)

Fineness of Wool Fiber

The average fineness of the wool fiber is its dominant dimensional characteristic, greatly affecting its manufacturing value The fineness is judged in the trade mainly by visual inspection.

Since the wool fiber is of microscopic structure, the fineness is expressed on the basis of microscopical measurements, either as the width or diameter of the fiber, depending on the measuring method used.

In judging the diameter of the wool fiber with the eye, the aver-

TABLE 4
FINENESS DISPERSION RANGE OF WOOL FIBERS

Range (microns)	*Fine Wool*		*Medium Wool*		*Coarse or Long Wool*	*Carpet or Mixed Wool*
	Super merino	*Merino*	*Fine*	*Coarse*		
10 to 20	88	41	22	6	2	15
20 to 30	12	57	64	39	18	35
30 to 40	—	2	14	41	27	26
40 to 50	—	—	—	13	40	8
50 to 60	—	—	—	1	10	6
60 to 70	—	—	—	—	3	2
Over 70 (kemp)	—	—	—	—	—	8
Average microns	17	21	24	32	40	36
Grades	90s	70s	62s	48s	36s	—

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40 to 50	—	—	—	13	40	8
50 to 60	—	—	—	1	10	6
60 to 70	—	—	—	—	3	2
Over 70 (kemp)	—	—	—	—	—	8
Average microns	17	21	24	32	40	36
Grades	90s	70s	62s	48s	36s	—

age person is under the impression that the individual fibers are more or less uniform in fineness. As a matter of fact, the diameter of wool fibers varies greatly, even in the same fleece; it may range

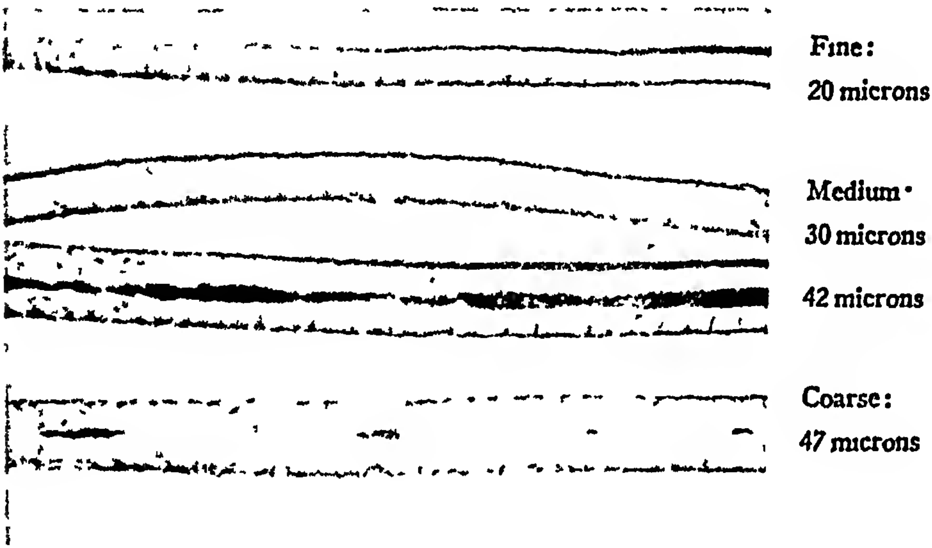


Fig. 20 Differences in fiber widths of wool.

from 10 to 70 microns. (Fig 20.) The least variation is found in the merino wool staple, which normally ranges from 10 to 30 microns, whereas a staple of carpet wool usually consists of fibers ranging from 10 to 70 microns and more. In addition, kemp fibers are present, the diameter of which ranges from 70 to 200 microns.

The dispersion range existing in commercial samples of four main types is illustrated in Tables 4 and 5.

Further variations within the whole length of the individual fiber are caused by physiological changes in the animals due to nutrition, gestation, weaning, or sickness. For instance, good feeding produces a heavier and coarser fleece, whereas malnutrition produces a lighter and finer fleece, in the same way lactation and the suckling of lambs reduces appreciably the fiber fineness, the fleece density, and the wool

production The tips of the staples, covering the back and side of the animal, are changed by atmospheric influences such as sun and rain.

TABLE 5

FINENESS MEASUREMENTS ON SIX MARKET GRADES

(Educational Set, U S Department of Agriculture, Nov. 1942)

	Fine	*½ Blood*	*⅜ Blood*	*¼ Blood*	*Low ¼ Blood*	*Common and Braid*
Number of fibers	600	800	1200	1200	1600	1600
Per cent of fibers from.						
10 to 20 microns	31 2	17 8	9 7	7.1	4 3	0 8
20 to 30 "	61.8	67 6	51 7	36.1	34.8	20.7
30 to 40 "	6 8	14 1	27.7	43 3	40.6	43.7
40 to 50 "	0.2	0 5	10.8	12.7	18 1	31 9
50 to 60 "	—	—	0 1	0 8	1 8	2.7
60 to 70 "	—	—	—	—	0 4	0 2
Average microns	22 8	24 9	29 12	31 43	33 05	36 71
Coeff of variation, %	23 2	21 3	26.7	25 1	25 4	20 7
A S T.M grade	64s/62s	60s	56s/50s	50s/48s	46s	40s

Note The samples in this new arrangement comprise bulk types and were selected to present a general average of the grade rather than the lower edge, as in the standard forms Microscopically the fine and ⅜ blood samples are on the lower edge, whereas the other four are perfect selections

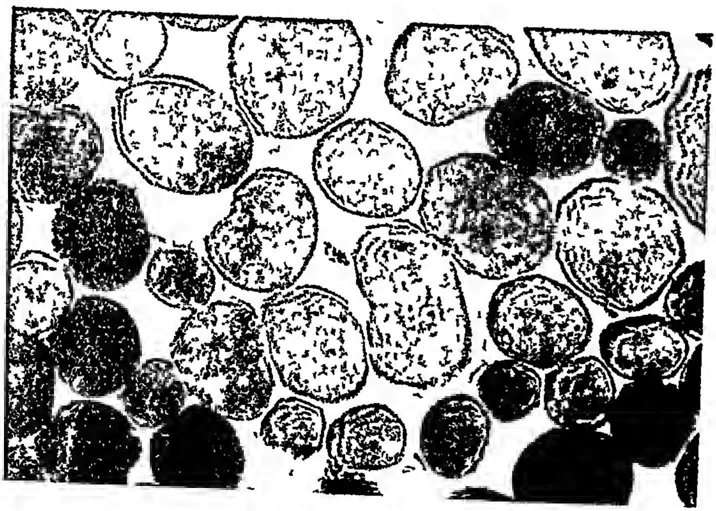


Fig 21 (X 500)
Cross section of wool showing the various shapes

Fiber Contour

The shape of the cross section varies greatly. Some cross sections are nearly circular. As a rule they are irregular and have a varying

degree of ovality or ellipticity (Fig. 21). The most common method of expressing the ellipticity is by the ratio of the major to the minor axis as the contour figure Barker has proved that in two wools of the same fineness the more circular wool spins better According to trade opinion the spinning properties of wool can be divided into three groups:

Group 1, very good spinning, with contour figure below 1 2,
Group 2, medium spinning, with contour figure 1 2 to 1 22,
Group 3, fair spinning, with contour figure above 1 22

Crimp in Wool Fiber

Wool fibers grow in a more or less wavy form and with a certain amount of twist. Crimp is probably a direct consequence of the formation of the fiber itself within the follicle Equality of crimp is associated with uniformity, and, therefore, a sign of good quality Crimps occur in the form of "waves" or "curls" They range from flat waves through normal waves to highly bent waves The number of waves in different wools is more or less an indication of fineness. Generally, the more crimps per inch, the finer the fiber, a condition that often strongly influences the wool buyer and the wool sorter in their judgment of the fineness It is, therefore, of great interest to the practical wool man to know how far the agreement is of value to him.

Bosman made a study of the relationship between the fiber fineness and crimping on South African wools Observations were carried out on 1000 samples produced in different areas of the Union Out of 1000 samples only 28 per cent showed a perfect agreement between the standards of crimps and those of fiber fineness The rest, or 72 per cent, did not conform, 36 per cent being finer and 36 per cent being coarser than the crimps indicated Of the 36 per cent that was coarser than the crimps indicated, 17 per cent was coarser by one quality number, 12 per cent was coarser by two quality numbers, and 6 per cent was coarser by more than two quality numbers Therefore, if a wool man bases wool quality on crimping, he can form a correct estimate in only 28 per cent of the cases This makes crimps alone an unreliable guide to fiber fineness for the South African clip as a whole. This is even more the case where individual samples are concerned

American wools do not differ from the above findings for South African wools McMurtrie established these facts fifty years ago He states as follows:

It is of course true that, as a general rule, the coarser fibers have fewer crimps per inch than the finer ones, yet the crimp of the fiber cannot always be accepted as a criterion of the absolute degree of fineness It is only necessary to make a few comparisons to see this, and though among the breeders considerable importance is attached to it and dealers and graders often use it in making their classifications based upon fineness, its true relation has been fully recognized by those who have made a careful examination of the staple in a scientific way. This has been confirmed in our own measurements This condition of the fiber cannot therefore be accepted as a reliable indicator of fineness, and some other means should be adopted for the determination of this latter quality to which such a high value is attached by both breeders and manufacturers, and concerning which, with reference to our American wools at least, there has been a marked demand for information

In the U S. Standard grades of raw wool, issued by the Department of Agriculture, the relationship of the crimps and the grade of wool was found as shown in Table 6.

TABLE 6
GRADE AND CRIMPS IN WOOL

Grades	*Number of Crimps per Inch*	*Grades*	*Number of Crimps per Inch*
Very fine	22 to 30	¼ blood	5 to 8
Fine	14 to 22	Low quarter	2 to 5
½ blood	10 to 14	Common	0 to 2
⅜ blood	8 to 10	Braid	0 to 1

In making up these standard grades, it is very difficult to select individual staples for this purpose by visual inspection only. Microscopical measurement is necessary to establish the correct grade The greatest deviation from the rule is observed in wools with highly or over-bent waves and in wools with adverse or flat waves In wools with a high amount of grease, the crimps are more numerous in contrast to dry wool, which looks coarser.

Length of Wool Fibers

The length of the fiber plays an important part as a quality factor, as "combing" and "clothing" wools are classified according to their length. Generally speaking, "clothing wool" is understood to be wool with an average staple length below 1½ inches, whereas "combing wools" commonly range from 2½ to 7 inches. Since the wool fiber is not a straight fiber but exhibits crimps and curls, the

measurement of the proper fiber length is complicated by its waviness So far there is no satisfactory method for the direct determination of the fiber length Depending upon the number of crimps, the stretched length may be 1 2 up to 1 9 times the natural length The various methods employed for length measurements are discussed in Chapter 23.

The length of the wool fibers varies in large limits not only in different breeds but also on the same animal The average length variation of twelve-month-grown wool of the main breeds is illustrated by Table 7.

TABLE 7
VARIATION IN AVERAGE LENGTH OF WOOL FIBERS

Wool Type	*Breeds*	*Length Variation (in inches)*
Fine	American merino	1½ to 3
	Rambouillet (U. S)	2½ to 3½
	Australian merino	3 to 5
Medium	English Down	2 to 4
	Corriedale	3 to 7
Coarse	Romney	5 to 6
	Leicester English	6 to 8
	Cotswold	10 to 14

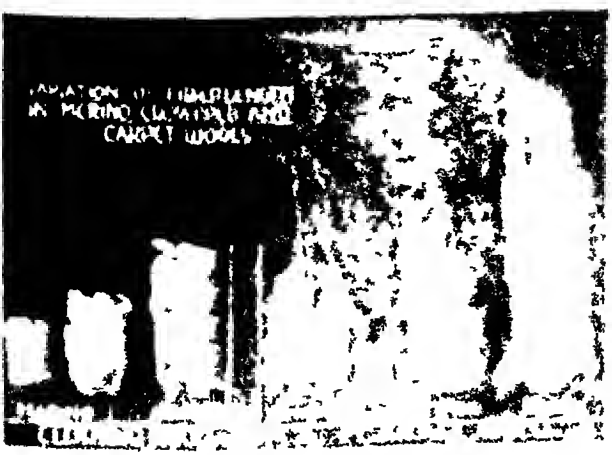


Fig 22 Fiber length [illegible] and carpet [illegible]
[illegible]

These figures [illegible] that [illegible] is [illegible] associated with [illegible] fiber [illegible] wools are [illegible] In [illegible]

short, medium, and long fibers, because the wool does not grow uniformly long out of the skin.

Breaking and Tensile Strength of Wool Fibers

Breaking strength is considered to be the force required to effect the rupture of a fiber or a fiber bundle, whereas tensile strength represents the breaking strength calculated on unit area. The whole literature reflects the difficulty in obtaining average strength figures for any type of wool or hair fibers based on single fiber tests. By breaking a large number of fibers, in the form of bundles, a much clearer insight can be obtained into the relationship between fineness and strength In a study of South African merino wools conducted by Bosman, Waterston, and Van Wyk, using the bundle method, 100 fibers per sample, the following was established:

Within the same staple, the coarse fibers were 52 per cent stronger per fiber than the fine fibers; there was a significant correlation of 0 9508 between fiber diameter and breaking strength and a significant negative correlation of 0.4822 between the fiber diameter and tensile strength The average breaking strength per fiber was 1 to 11 grams (mean 5 50 grams) and the tensile strength 600-1600 kg/sq cm (average 1243). With different samples, the correlation between fiber fineness and breaking strength was significant, that between fiber fineness and tensile strength insignificant. The regression coefficient of the breaking load on fiber fineness was 0 445, indicating that, on an average, every increase of one micron in fiber diameter was associated with an increase of 0 445 gram in the breaking strength

Kronacher reported a regression coefficient of 0.5819. Recent research conducted by the Forstmann Woolen Company has produced results (Tables 8 to 10) which show that the wool fiber possesses considerably greater strength than it had hitherto been credited with Tables 8 and 9 show the average breaking and tensile strength as measured on the official U. S. Top Standards while Table 10 shows the breaking and tensile strengths of important hair fibers The above investigation was conducted on two sets of official U. S Top Standards, one of which was the original standard compiled and promulgated in 1926 of grades obtained from wools of foreign origin The other, effective in January 1940, was derived from domestic wools only. The 1926 standard consisted of twelve grades, ranging from 80s through 36s, of which the fine grades probably represent wools of Australian origin, and the medium and coarser grades are presumably drawn from English or New Zealand clips The latter set of standards, effective in 1940, was composed of eight domestic grades, ranging from 80s through 50s quality.

TABLE 8

STRENGTH OF FOREIGN WOOL TOPS

(Official U S Top Standards, Box 134 Effective January 1, 1935)

Bundle Test Conditions. 65% R H. at 72° F.

Grade	Fineness (microns)	Approx No of Fibers	Breaking Strength		Tensile Strength	
			Bundle (kg)	Single Fiber (grams)	Kg /cm ²	Coefficient of Variation (per cent)
80s	19.5	2990	14 3	4 78	1597	1 7
70s	20 8	2630	13 8	5 25	1546	1 0
64s	21 9	2380	14 0	5 88	1564	2 3
60s	23 5	2060	14 7	7 14	1649	1 2
58s	24 8	1850	15 6	8 43	1743	1 2
56s	26 9	1570	16 2	10 32	1816	1 6
50s	30 4	1230	17 0	13 82	1903	1 3
48s	33 0	1050	16 8	16 00	1877	2.0
46s	34 8	940	17 1	18 19	1904	2 5
44s	36 6	850	17 3	20 35	1929	1 3
40s	38 3	780	18 4	23 59	2053	1 4
36s	39 3	740	19 0	25 68	2124	2.0

Bundle length
2 in for grades 80s, 70s, 64s, 60s, 58s, 56s
3 in for grades 50s, 48s, 46s, 44s, 40s, 36s
Coefficient of correlation
Fineness breaking strength, +0 990
Fineness tensile strength, +0 966

Average bundle size 2 in , 0 06 gram
3 in , 0 09 gram

The breaking strength results signify the average of ten tests, performed on bundles of equal weight in relation to the bundle length for each of the wool grades analyzed (30 milligrams per inch of fiber length). In view of the low variations in the individual test results, ten tests were deemed adequate In consequence, the number of fibers per bundle varies with the diameter of the fibers

The converted results obtained for the breaking strength of the individual fibers for the foreign and domestic wools indicate that direct relationship exists between the fiber diameter and fiber breaking strength This is in agreement with the findings of Bosman and associates However, a higher correlation was found on the tests performed on fibers in top form than in the results obtained

TABLE 9

STRENGTH OF DOMESTIC WOOL TOPS

(Official U S. Top Standards, Effective January 1, 1940)

Bundle Test Conditions. 65% R H. at 72° F.

Grade	Fineness (microns)	Approx No of Fibers	Breaking Strength		Tensile Strength	
			Bundle (kg)	Single Fiber (grams)	Kg /cm.²	Coefficient of Variation (per cent)
80s	19 5	3000	13 7	4 57	1526	1 6
70s	20 0	2840	13 7	4 82	1537	1 6
64s	21 8	2350	13 3	5 66	1499	3 9
62s	23 5	2060	13 2	6 41	1477	3 8
60s	24.7	1820	13 3	7.31	1490	2 2
58s	25 8	1680	13 5	8 04	1510	1 3
56s	27 7	1450	14 7	10 14	1649	1 2
50s	30 2	1260	14.4	11 43	1614	2 7

Coefficient of correlation
Breaking strength, 0 9887
Tensile strength, 0 6195

Average bundle size 0 06 gram
Bundle length 2 in

by Bosman which were derived from wool in staple (fleece) form This is understandable in view of the greater uniformity and degree of mixing obtained in commercial top samples. Each top standard represents a cross section or composite average of wools obtained from a variety of clips of diverse origin A significant correlation of 0 990 between fiber diameter and breaking strength was found for the entire set of foreign wool samples, as compared with a correlation of 0 992 for the grades 80s to 50s inclusive. For the domestic wools, a correlation of 0 989 between fineness and breaking strength for the grades between 80s and 50s was observed

A significant difference is evident in the correlation between fiber diameter and tensile strength for foreign and domestic wools Comparison between the correlation coefficient of domestic and foreign fine wools (fineness range between 80s and 50s) reveals a significant plus correlation for the foreign wools of 0 957 and a significant plus correlation of 0 620 for the equivalent domestic grades A further characteristic of the results obtained on the foreign and

TABLE 10

BREAKING STRENGTH OF VARIOUS HAIR FIBERS

Bundle Test. Conditions 65% R. H. at 72° F

Type	Fineness (microns)	Approx. No. of Fibers	Breaking Strength: Bundle (kg.)	Breaking Strength: Single Fiber (grams)	Tensile Strength: Kg./cm.²	Tensile Strength: Coefficient of Variation (per cent.)
Human hair Female, 14 yr (light brown) *	58.6	330	21.9	66.36	2439	2.3
Female, 38 yr (dark brown) *	84.8	160	21.4	133.75	2388	2.6
Horsehair Female, tail, 9 yr (blue-ronde) *	260.0	17	15.1	888.24	1681	5.7
Female, tail, 15 yr (chestnut) *	181.0	35	17.1	488.57	1914	5.5
Mixed, mane Argentine (dirty white) *	129.0	70	16.1	230.00	1799	3.1
Cow hair Mixed, tail (dirty white) *	187.0	30	18.1	603.33	2023	3.8
Mohair super kid top	25.4	1800	19.1	10.61	2154	2.4
36s top	28.7	1360	20.0	14.70	2231	1.1
22s top *	36.4	870	18.6	21.38	2138	2.5
Cashmere top *	15.0	5000	12.7	2.54	1444	3.3
Camel's hair Fine top *	20.7	2750	15.4	5.60	1790	3.2
Coarse top	26.6	1570	16.3	10.38	1808	3.2
Alpaca White top *	27.0	1640	17.1	10.43	1820	0.7
Brown top	27.0	1540	15.4	10.00	1747	2.6
Black top	27.0	1590	15.3	9.62	1682	3.4

Bundle length:
3 in. for Argentine horsehair, kid mohair, 36s mohair, 22s mohair, alpaca white, brown, black
2 in. for Human hair, female 14 yr, female 38 yr, horsehair tail, 9 yr, tail 15 yr, cow hair, camel's hair, fine, coarse.
1 in. for Cashmere.

* Correlation coefficient of fibers marked
Fineness breaking strength, 0.980
Fineness tensile strength, 0.076

Average bundle size
1 in., 0.03 gram
2 in., 0.06 gram.
3 in., 0.09 gram

domestic wools showed that the tensile strength distribution fell into three definite groups, which more or less coincide with the three main wool types—fine, medium, and coarse. This factor is even more pronounced in the domestic wool samples. There is no correlation between fiber diameter and tensile strength in the fine grades, 58s and up, whereas there is a definite upward trend in the medium (crossbred) types, 56s to 50s. The regression coefficient of the breaking load on fiber fineness for domestic wool is 0.549 gram, indicating that, on an average, every increase of 1 micron in fiber diameter is associated with an increase of 0.549 gram in the breaking strength.

In the wet state, wool loses from 10 to 25 per cent of its strength In Table 11 are shown the relationships between the dry and wet strength of 1940 standard tops.

TABLE 11

WET AND DRY TENSILE STRENGTH OF WOOL IN KG/CM²

Top Grades	*Dry*	*Wet*	*Loss % of Dry*	*Top Grades*	*Dry*	*Wet*	*Loss % of Dry*
80s	1525	1197	21 5	50s	1614	1321	18 1
70s	1537	1199	22 0	48s	1877	1544	17 8
64s	1499	1212	18 3	46s	1904	1641	13 9
62s	1477	1244	15 8	44s	1929	1633	15 4
60s	1490	1269	14 8	40s	2053	1751	14 8
58s	1510	1300	13 9	36s	2124	1835	13 7
56s	1649	1300	21 1				

The strength data on the specialty hair and the other animal fibers reveal that each type of fibers seems to have its definite strength level, with the human hair the strongest Using 100 per cent as the tensile strength of human hair, tensile strengths of the various fibers can be rated as in Table 12

TABLE 12

STRENGTH RELATIONSHIP FOR VARIOUS ANIMAL FIBERS

Type of Fiber	*Tensile Strength (per cent)*	*Type of Fiber*	*Tensile Strength (per cent)*
Human hair	100	Camel's hair	75
Mohair	90	Alpaca	72
Long wools	80	Medium wools	70
Horsehair	75	Merino	62

Elasticity of Wool Fiber

If a wool fiber is slowly elongated without rupture, a definite extension will result. When the load is subsequently released the fiber makes an immediate partial recovery, leaving a residual extension, resulting in a "temporary set," which the fiber slowly loses if given time.

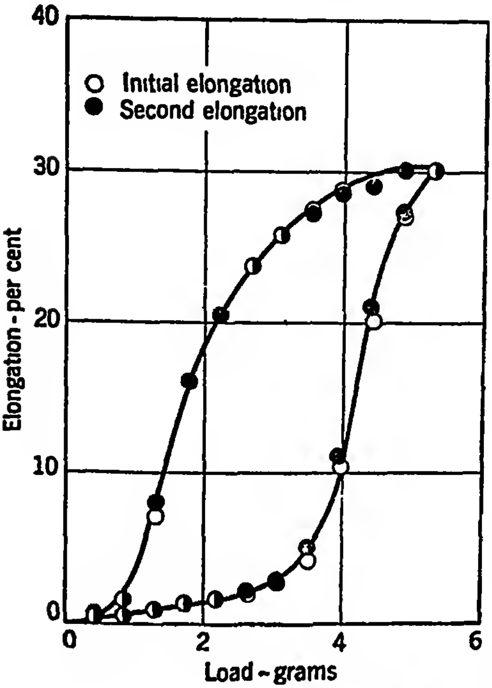


Fig 23 Typical untreated wool fiber during the two stress-strain cycles, 24 hrs apart (30 per cent index equals 0 99) (*Harris*)

Speakman has demonstrated that wool fibers can be elongated 30 per cent without permanent deformation or weakening if the duration of the strain is short. Harris and Sookne plot the stress-strain characteristic of individual wool fibers automatically Figure 23 shows the behavior of a typical wool fiber during two successive stress - strain determinations The fiber was allowed to relax for approximately twenty-four hours between the first and second extentions It is noteworthy that the entire stress-strain cycle is reproducible The 30 per cent index is the energy required to elongate a fiber 30 per cent after a treatment divided by the simi-

TABLE 13

MODULI OF ELASTICITY FOR WOOL FIBERS FROM DIFFERENT BREEDS

(Pounds per square inch.)

Breeds	*Total Stretch in Millimeters*					
	1 00	2 00	3 00	4 00	6 00	8 00
Lincoln	372,374	200,335	139,367	108,826	84,774	81,351
Oxforddown	486,689	269,263	186,149	144,592	109,250	101,780
Cotswold	345,662	186,753	130,236	101,865	78,700	73,343
Merino	395,237	233,950	169,775	138,819	109,486	95,537
Southdown	523,813	310,802	223,349	173,850	134,454	—
Averages	424,755	240,221	169,735	133,500	103,333	88,003

lar energy requirement prior to the treatment, which in the above case amounts to 0 99.

McMurtrie established the moduli of elasticity of wool fibers (20-millimeter length) from different breeds These results are found in Table 13 The modulus of elasticity for merino wool is pretty nearly the average for the five breeds considered The value of the modulus diminishes very rapidly as the stretch increases.

Resilience of Wool Fiber

Resilience is the springiness of a fiber mass, or the ability of a fiber to come back to its original volume after being compressed. This property is especially predominant in wool. It is by reason of this quality that wool fabrics hold their shape, drape gracefully, and do not wrinkle easily This property is desired to a high degree in carpet wools There is no accurate way of measuring this property as yet The force with which the wool fiber resists compression is well known to the wool packer The various wools differ considerably in this respect

Rigidity of Wool Fiber

The rigidity of the wool fiber is the property which determines its resistance to the insertion of twist, and is, therefore, of great interest in spinning The rigidity depends to a marked degree on the amount of water combined with the wool, actually, the rigidity of dry wool fibers is about fifteen times greater than that of wool fibers saturated with water. For this reason all modern spinning rooms are equipped with humidifying systems to keep the humidity of the spinning room as high as possible Normally from 70 to 80 per cent relative humidity keeps the moisture in wool between a 15 and 18 per cent regain

Felting

Felting, one of the most important characteristics of wool, is lacking in many other textile materials, and is of a purely physical nature To make felting possible a fiber must possess a surface scale structure, ease of deformation, and the power of recovery from deformation Under the influence of pressure, heat, and moisture the wool fiber tends to migrate in the direction of its root end, owing to its scale structure. The outstanding scales act

as fish hooks, which allow the fiber to move in only one direction The movements of the fibers against each other and the utilization of the air spaces brings about a very close interlocking Moisture and heat assist in making the fullest use of the fiber crimp, as the natural wave formation is especially favorable to the movements of the fibers Moisture favors the adhesion of the fibers to each other, besides causing a swelling and increasing the elongation and elasticity. Only a few of the fibers in a yarn possess complete freedom of movement, the greater number being free only along a part of their length, hence migrate by extension in a manner best described by Arnold in his "earthworm theory" as follows:

> The pressure of the fulling rolls brings about the closest possible contact between the fibers, whereby the scales find the necessary resistance on each other. The frictional movement forces the hair in the direction of its root end, either wholly or partly, causing a stretching Because of its elasticity, the moist fiber tends to counteract this elongation This occurs in the direction of the root, and because the fiber is held in position firmly by the scales, a steady forward movement results When pressure is released the stretched fibers contract and cause shrinkage of the fibers by drawing other fibers together, forming a close and compact fiber mass

Luster in Wool

Wools vary considerably in luster It is natural for certain wools to be lustrous This luster cannot be noted in a single hair, but in locks and accumulated quantities Luster varies with origin and breed of animal and with climate The trade differentiates between *silver* luster, *silk* luster, and *glass* luster The silver luster is especially prominent in the finest and strongly crimped merino wools where it is often characterized as a mild luster. The silk luster is present in the long staple and long waved wools, represented by the English wools, and designated as "luster wools." The Lincoln and Leicester wools are especially valued for this reason.

The highest, the glass luster, always points to the straight, smooth hairs which are especially apparent in goat hair, such as mohair The glassy hairs on sheep are found on the head, neck, tail root, and lower part of the legs This variation in luster of different wools is of great value in the manufacture of certain types of materials, because it influences the beauty and vividness of color and appearance of goods The luster of wools can be altered through changes in the physical structure Epidermis cells may have lost their smoothness, and the rough surface makes an unfavorable reflection surface Such wools are known as dull wools The rough surface

is caused by atmospheric influences or mildew whereby the scales are partly destroyed or dissolved.

Color of Wool

Wool from most domesticated breeds of sheep is nearly always white, though it may occur in the natural colors of gray, brown, or black The degree of whiteness may vary considerably. Of the domestic wools, the Wyoming wools are known for their whiteness, whereas many Texas wools are more ivory in shade. Australian wools are generally pure white. South American wools, such as Montevideo wools, and some of the Buenos Aires wools, may range from light ivory to dirty ivory shade In some instances the whole fleece is colored, whereas in others the color may be limited to the head and leg parts For example, the English Down sheep are recognized by the chocolate-brown or black hairs covering part of the head and legs The largest amount of colored wools is produced by the primitive breeds growing carpet wool types.

Beyond the difference in color, there is no noticeable difference in structure or properties between black wool and white wool Climate seems to have no influence on the occurrence of black wool, and it is as liable to occur in one breed as in another The amount of black wool appearing in the American domestic breed is about 3 to 5 per cent of the total clip

The color is produced by pigments, which are distributed mainly through the cortical and medullary cells There are two forms present: diffuse or non-granular and the granular, the latter form predominating. The epidermis cells are free from coloring matter The photomicrograph of Fig. 24 illustrates these facts

Fig 24 Cross section of natural colored wool fibers (X 500)

Specific Gravity of Wool Fiber

Wool is one of the lightest natural textile fibers The density or specific gravity of wool is one of its fundamental characteristics, which seems to be more or less constant in all varieties and conditions of the fiber. Specific gravity of wool, as recorded in the literature, varies according to the liquid used in its determination According to King, the specific gravity as found in benzene seems to be the correct value, established as 1 304 Van Wyk and Nel determined the specific gravity of fifty-four samples of South African merino wool. The mean value was 1 3052 at 25° C, water at 4° C, with a standard deviation of ±0 0035 and a coefficient of variability of ±0 27 per cent No correlation was found between specific gravity and fiber fineness

No appreciable differences are found in medulla-free wools, whether merino or crossbred Lower values are obtained in medullated wools as the tendency toward kempy nature increases This is undoubtedly due to the incomplete removal of the air present in the medulla

Moisture Content of Wool Fiber

Wool is more hygroscopic than any other fiber. However, the amount of moisture varies considerably according to the humidity and temperature of the atmosphere

The condition of the material also has an effect upon its moisture content The presence of more or less hygroscopic wool fats, oils, acids, and alkalies, the degree of looseness or compactness during manufacturing, and the changes the fiber undergoes in processes such as scouring, dyeing, steaming, and drying are all factors which may influence the moisture content The effect of the length of time during which atmospheric humidity acts upon the fibers is important The change of the moisture content depends greatly upon the nature of its surface accessibility For instance, wool spread out in thin layers is influenced far more easily than compressed or baled wool, especially that stored in large piles in closed warehouses

Aside from the area of surface exposure, the rate with which the fiber takes up or relinquishes moisture depends chiefly upon the time of exposure to a particular humidity Generally speaking, up to a certain point, the rate of moisture desorption exceeds the rate

of adsorption until a state of equilibrium is reached. In practice, this state is usually reached in four to five hours.

The changes occurring in the regain of wool by exposure to atmospheres of different humidity at a constant temperature are recorded in Table 14, compiled by the English Wool Industries Research Association.

TABLE 14

AVERAGE MOISTURE REGAIN OF WOOL IN VARIOUS FORMS

Various Forms	R. H. of Atmosphere (Per Cent) at 72° F						
	43.3	55.4	62.3	74.6	81.5	86.2	90.0
	Regain (Per Cent) Mean Values						
Scoured wool	12.08	14.22	15.51	16.55	17.86	19.61	21.17
Card ball	12.13	14.35	15.52	17.02	18.73	20.86	22.65
Backwashed ball	11.92	14.19	15.29	16.86	18.52	20.58	22.38
Noils	11.66	13.59	14.93	15.79	17.17	18.89	20.43
Tops	11.77	13.94	15.07	16.56	18.12	20.15	21.92
Yarns	12.22	14.36	15.36	16.86	18.50	20.31	21.97

The moisture content of wool in the grease is considerably lower than that established for scoured wool. Sommer reports the figures shown in Table 15.

TABLE 15

MOISTURE CONTENT OF GREASE WOOL IN PERCENTAGE OF DRY WEIGHT

Relative Humidity (per cent)	Moisture Regain (per cent)
30	6.0 to 8.5
40	7.2 to 9.7
50	8.5 to 11.0
60	9.6 to 12.2
70	11.0 to 13.0
100	39.0 to 48.0

A study of the variation in the content of the hygroscopic moisture in worsted yarns has been made by Hartshorne. This study led to the establishment of a standard for conditioning wool in the United States

The complexity of the behavior of the wool toward moisture has been clarified considerably by Speakman, Stott, and Cooper. Speakman was the first to show that a marked hysteresis exists in the moisture content of wool between adsorption and desorption conditions In dealing with six different types of wool, Speakman found them remarkably similar in adsorptive power, the affinity

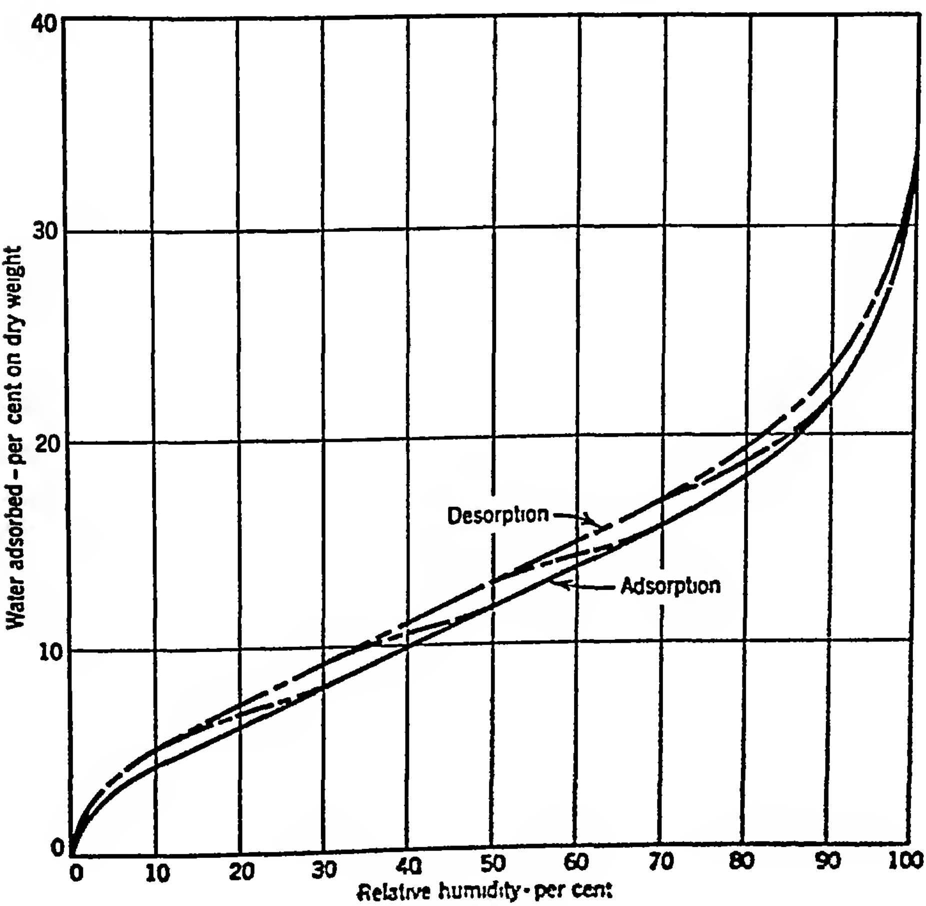


Fig 25 Adsorption and desorption curves for wool (*Speakman and Cooper*)

for water appears to increase slightly as the wool becomes coarser. In view of the alternations in the adsorption and desorption experienced by wool in everyday processing, it is important to know the range of humidity over which wool must be dried in order to pass from the state of taking up water to the state of giving off water, when the regain is below saturation In their latest study, using Australian 70s merino wool, Speakman and Cooper obtained the data represented in graphical form in Fig 25 and in Table 16. The temperature maintained throughout these tests was 25° C. (77°F)

TABLE 16

INFLUENCE OF HUMIDITY ON MOISTURE EQUILIBRIUM ON WOOLS ADSORBING AND DESORBING AT 77° F.

Relative humidity (per cent)	20	40	60	65	70	80	90
Adsorption	6 3	10 0	13 5	14 4	15 5	18 1	21 9
Desorption	7 5	11 2	14 8	15.8	16 9	19.4	23 1

As shown in Fig. 25, the short-range desorption experiments define the course of drying from adsorption to desorption conditions for wools at different initial regains. The range of humidity over which wool must be dried in order to pass from adsorption to limiting desorption conditions seems to be independent of regain and is about 18 per cent.

In regard to the influence the temperature of drying has on the affinity of wool for water, Speakman and Stott reached the following conclusions. (1) When wool is dried from regains below saturation, its absorption power decreases with increasing temperature of drying The reduction is produced by partial as well as complete drying, but not by drying from saturation, nor by heating wool at a low temperature (2) A normal affinity for water may be restored to wool which has been dried at a high temperature, by allowing it to reach saturation with water vapor. On the other hand, the reduced adsorptive power of the wool heated over water at a high temperature is irreversible The results of their studies are shown in Fig. 26

Interesting results were obtained by Wiegerink in the determination of the amount of moisture retained by the various fibers when brought to equilibrium at temperatures ranging between 100°F (37 8°C) and 302°F (150°C.), with various humidities at each

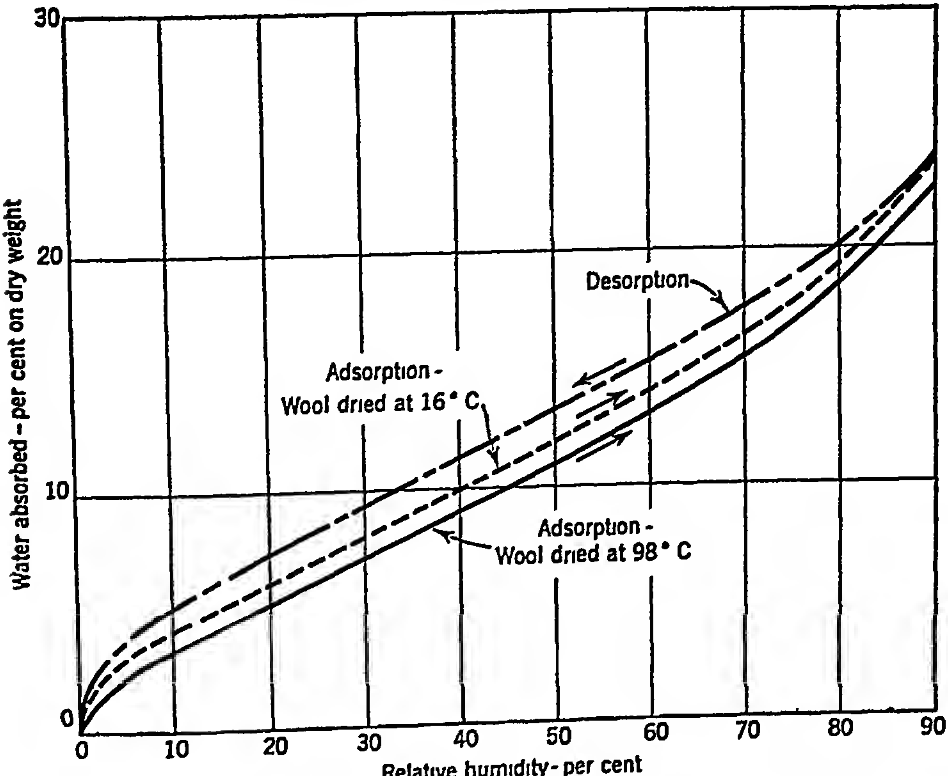


Fig 26. Adsorption and desorption curves for wool dried at 16° and 98° C (*Speakman and Stott*)

temperature to characterize the moisture content—relative humidity relationship This information provides a basis for determining the limiting moisture content for textile fibers, which may be approached in any specified industrial drying process under definite atmospheric conditions

The results of the study on clothing wools as reported by Wiegerink are given in the form of graphs showing moisture content against R. H (see Fig 27). These curves indicate the limits in moisture content which may be expected in wool fibers, if the atmosphere in contact with the fiber during drying is maintained at any desired temperature and relative humidity. The desorption curve for the given temperature is to be used if the fiber is initially wet, and the adsorption curve is to be used if the fiber is initially dry. Wiegerink emphasizes that the curves apply, of course, only to the samples examined The two wools tested were in the form of

as 2 per cent in scale weight between port of embarkation and its destination in the United States. Because importation of wools involves duty considerations, the importance of this factor is evident In the commercial relations between wool dealers, manufacturers, and government agencies, this has led to the establishment of conditioning houses, where the actual amount of fiber and moisture in any given lot of wool, top, or yarn is carefully ascertained The true weight is based on a standard per cent of moisture or "regain." In Europe, this practice has been long established, whereas in this country its development is quite recent. Table 17 shows the specifications in use in the United States

TABLE 17

AMERICAN MOISTURE REGAINS

Form or Condition	*Regain Per Cent*
Scoured wool	13 63
Dry-combed top (French)	15 00
Oil-combed top (Bradford)	15 00
Woolen yarns	13 00
Oil-spun worsted yarn (Bradford)	13 00
Dry-spun worsted yarn (French)	15 00

The U S Treasury Department specifies 12 per cent moisture content for scoured wool to be used for calculating the clean net weight of grease wool. Table 18 shows the specifications for moisture regains in use in Europe.

TABLE 18

EUROPEAN MOISTURE REGAINS

Form or Condition	*Regain Per Cent*
Washed fleeces	17 00
Scoured wools	18 00
Top in oil (Bradford)	19 00
Top (French)	18.25
Bradford and French worsted yarns	18 25
French noils	16 00
Noils (Lister and Noble)	16 00
Carbonized and scoured noils	17 00
Shoddy	17 00
Woolen yarns	17 00

Electric Properties of Wool

Wool is a poor conductor of electricity It is easily charged, however, with electricity by friction, forming static electricity which often interferes in carding, spinning, and dry finishing. This is particularly noticeable on dry, cold winter days, when low relative humidity reduces the moisture content in wool below 12 per cent Errera and Sack found that the dielectric constant of wool and mohair fibers and human hair is 4.2, at frequencies between 13 million cycles and 120 kilocycles

Thermal Qualities of Wool

There has been a wide divergence of opinion regarding the warmth of wool as compared with cotton, silk, and rayon fibers and fabrics Throughout the literature on the thermal properties of textiles, there are a general lack of data and great discrepancies in the results

One of the necessary conditions for human body comfort is that the skin temperature be maintained at 91°F. This requires that the total heat losses be just balanced by the heat produced within the body If more heat is lost than is produced, the skin temperature is lowered, similarly, if more heat is produced than is lost, the skin temperature rises One becomes uncomfortable if the skin temperature changes more than one or two degrees in either direction The body's natural methods of counteracting abnormal skin temperature are by exercise (shivering is a form of exercise) when it is too low and by greatly increased perspiration when too high.

Clothing serves as a protective layer over the skin to prevent excessive heat exchange between the body and its surroundings This protective layer greatly decreases the circulation of air next to the skin thereby reducing the heat loss from the body when the surrounding air is cooler than skin temperature It also decreases the amount of heat absorbed by the body when the surrounding air is warmer than skin temperature It is obvious then, that the effectiveness of clothing in keeping the body comfortable will depend on a number of factors, the most important being (1) the insulating properties of the fabric used, (2) the surrounding air temperature, (3) the styling of the clothing, (4) the activity of the body, and (5) the wind velocity. The first of these factors is of primary interest and will be discussed at some length after the other factors have been briefly considered

Clothing design has considerable effect on thermal properties Open-necked coats or sleeves and flapping trouser bottoms permit a very substantial increase in air circulation over that when these areas are tightly closed Similarly, any motion of either the air or the body will also increase the heat loss An increase in the difference between the skin and surrounding air temperatures requires greater insulation, as we all know.

Scientific tests made of the insulating properties of fabrics have produced some astonishing results They are astonishing only because of their contradiction of common conceptions, actually, upon careful consideration, they are most logical.

The thickness of a fabric determines its warmth This fact has been proved conclusively by several independent scientific studies After an exhaustive study of warmth of all types of blankets, Schiefer of the National Bureau of Standards concludes

> The analysis of many thermal transmission measurements indicates that the kind of fiber has no effect on the thermal insulation of fabrics The small effect which might be due to the kind of fiber is either too small to measure or is masked by other factors which have a much greater effect As far as the measurable properties of blankets are concerned, the only property which is definitely related to the kind of fiber used is the compressional resilience The compressional resilience of blankets is related linearly to the wool content of wool-cotton blankets The relationship has not yet been established for other fiber mixtures, except that we know that viscose rayon lowers the resilience more than cotton, and that acetate seems to lower it less Since a definite relationship exists between the thickness and thermal insulation of fabrics it follows that if any factor affects the thickness it would likewise affect the thermal insulation A blanket containing all wool and having a high compressional resilience probably will retain its original thickness more nearly during use than a blanket made from cotton or viscose rayon It therefore might be expected to retain its original thermal insulation more nearly than a cotton or rayon blanket

The Forstmann Woolen Company has done considerable research on the thermal properties of fabrics Fig 28 shows the variation of warmth with fabric thickness, as determined by their work Warmth, or thermal insulating value is defined as the ratio of the difference between the heat losses of the unclothed body and of the clothed body to that of the unclothed body, or

$$\text{Warmth} = \frac{\text{Heat loss of unclothed body—Heat loss of clothed body}}{\text{Heat loss of unclothed body}}$$

In this figure 100 per cent warmth would correspond to no heat loss through the fabric It is seen that a fabric 020 inch thick will give 29 per cent warmth, while the thickest coating, 250 inch thick will give 72 per cent warmth.

It should be noted that a fabric twice the thickness of another fabric does not give twice the warmth; for example, a fabric .200 inch thick gives 70 per cent warmth while one .100 inch thick gives 60 per cent warmth In fact, any increase of thickness above 250 inch provides practically no increase in warmth. It has been estimated that a total of twelve inches would be required to reach 100 per cent warmth Since this curve is valid for all apparel fabrics it is evident that under ordinary conditions the warmth of a fabric is not affected by the weight and construction of fibers used in the fabric, e. g, a cotton flannel is just as warm as a wool worsted if they are of the same thickness This predominence of thickness over all other fabric variables in determining warmth has also been reported by Rees, Baxter, Cassie, Sommers and other workers

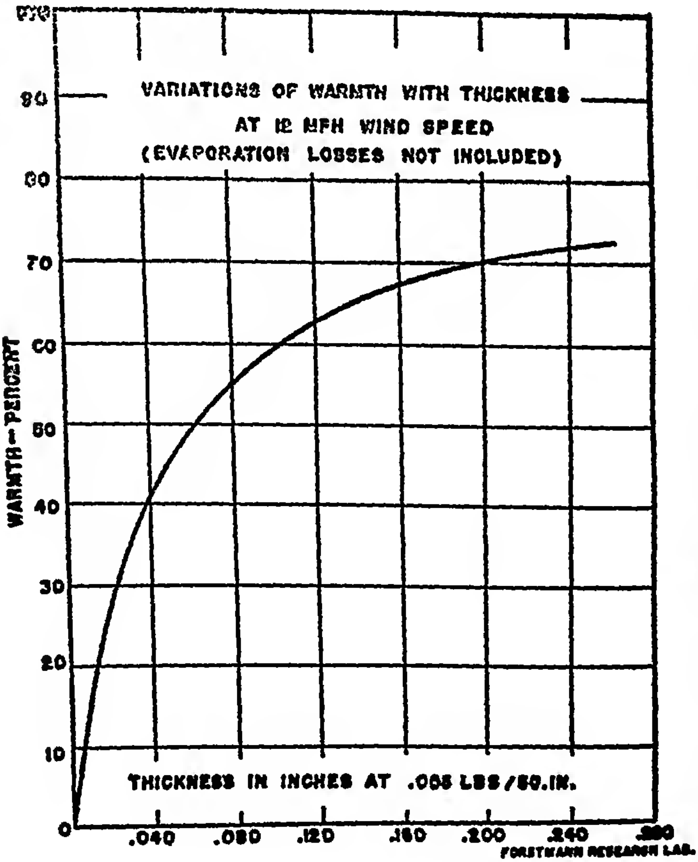


Fig 28 Variation of warmth with fabric thickness

While the above warmth curve was obtained with a wind velocity of 12 miles per hour, the same general relationship between thickness and warmth holds for other wind speeds. At higher wind speeds the warmth will be greater since the heat loss from the unclothed body increases more rapidly than that from the clothed body This increase in heat loss with increasing wind speeds is due

primarily to the decrease in the effective thickness of the static air layer above the fabric Rees states the thickness of this layer is .32 inches in still air.

The effect of the openness or air permeability of a fabric is a somewhat disputed subject Results of tests conducted by the United States Testing Company for Forstmann Woolen Company show that there is no absolute permeability effect on warmth even at 24 miles per hour wind speed Rees obtained very little correlation between warmth and air permeability, however, Nevin and Babbitt, Day, Summers and others have found that the openness of the fabric may be an important warmth factor, particularly under severe climatic conditions encountered in military applications

It is generally agreed that the effectiveness of a fabric as an insulator is determined by the thickness of the air layer which has been

TABLE 19

FIBER WEIGHT AND FIBER VOLUME IN WOOL FABRICS

Oz /running yd 56" wide	*Oz /sq yd*	*Fiber Volume cu in /sq yd*	*Grams/ sq meter*	*Fiber Volume cu cm/sq meter*
6	3 87	5 13	130 5	100 4
7	4 50	5 97	152 2	117 1
8	5 14	6 82	174 0	133 8
9	5 79	7 68	195 8	150 61
10	6 43	8 53	217 5	167 3
11	7 07	9 37	239 3	184 1
12	7 72	10 24	261 0	200 8
13	8.36	11 09	282 8	217 5
14	9 00	11 94	304 5	234.2
15	9 65	12 80	326 3	251 0
16	10.29	13 65	348 0	267 7
17	10 93	14 50	369 8	284 5
18	11 57	15 34	391 5	301 2
19	12.22	16 21	413 3	317 9
20	12 86	17 06	435 0	334 6
21	13 50	17 90	456 8	351 4
22	14 15	18 79	478 5	368 1
23	14 79	19 62	500 3	384 8
24	15 43	20 46	522 0	401 5
25	16 07	21 31	543 8	418 3
26	16 72	22 18	565 5	435 0
27	17 36	23 02	587 3	451 8
28	18 00	23 87	609 0	468 5
29	18 65	24 73	630 8	485 2
30	19 29	25 58	652 5	501 9
31	19 93	26 43	674 3	518 7
32	20 58	27.30	696 0	535 4

entrapped by the textile fibers. Of course, a somewhat greater warmth is obtained with two fabric layers than with a single layer of the same total thickness due to the still air layer between the two fabrics The replacement of the entrapped air with a less efficient insulating material such as water, will greatly decrease the warmth of the fabric

When the thickness and weight of a wool fabric are known, it is possible to determine the percentages of fiber volume and air volume in the fabric Table 19 gives the fiber weight and fiber volume of wool fabrics ranging from 6 to 32 ounces per linear yard The calculations are based on a specific gravity of wool of 1 3. Table 20 shows the relationship between fabric weight, fabric thickness and per cent of air on the volume basis This interesting relationship was developed

TABLE 20

FABRIC THICKNESS FOR VARYING FABRIC WEIGHTS AND VOLUME AIR CONTENT PERCENTAGES

% Volume Air Content / Oz /running yd 56" wide	80	81	82	83	84	85	86
	Thickness in inches						
6	021	022	023	024	026	027	029
7	.024	025	027	028	030	032	034
8	.027	029	030	032	.034	037	039
9	031	032	034	036	039	041	044
10	034	036	.038	040	043	046	049
11	038	040	042	044	.047	050	054
12	041	043	046	048	051	055	059
13	.045	.047	.050	052	056	059	064
14	.048	050	053	056	060	064	068
15	051	054	057	060	064	069	073
16	055	058	061	064	069	074	078
17	058	061	.065	068	073	078	083
18	062	065	069	073	077	082	088
19	065	068	072	077	081	087	093
20	.069	072	076	.081	086	091	098
21	072	076	080	085	090	096	103
22	075	079	084	089	094	101	108
23	079	083	088	093	098	105	112
24	082	086	091	097	103	110	117
25	086	090	095	101	107	114	122
26	089	094	099	105	111	.119	127
27	.092	097	103	109	.116	123	132
28	096	101	107	113	120	.128	137
29	099	104	.110	117	124	133	142
30	103	108	114	.121	128	137	147
31	.106	112	.118	125	133	142	152
32	.110	115	.122	129	137	146	.157

by Mr. G H Lynen of the Forstmann Woolen Co The weight range of 6 to 32 ounces per running yard, 56 inch wide and thickness range of 020 to .250 inch correspond to the range of woolen and worsted apparel fabrics normally produced It is impractical to make fabrics of greater weight or thickness, since a garment made from such a fabric would be too cumbersome; also, as previously stated, little additional warmth is obtained with thicknesses over 250 inch The low limits of 6 ounces and 020 inch are determined by the difficulties encountered in spinning finer wool yarns

The fiber content range of 20 to 5 per cent with the corresponding air content range of 80 to 95 per cent is also determined by practical limits By severe applications of heat and pressure somewhat higher fiber contents may be obtained The resultant product is too stiff for

TABLE 20

FABRIC THICKNESS FOR VARYING FABRIC WEIGHTS AND VOLUME AIR CONTENT PERCENTAGES

(Thickness in inches)

87	88	89	90	91	92	93	94	95
032	034	037	041	046	.051	059	069	082
037	040	044	048	053	060	069	080	096
.042	046	050	055	061	069	078	091	110
047	051	056	.062	068	077	088	.103	123
053	057	062	069	076	086	098	114	.137
058	063	068	075	084	094	108	126	151
063	068	075	082	091	.103	117	137	.164
068	.074	081	089	099	111	127	148	.178
074	080	087	096	107	120	.137	160	.192
079	086	093	103	114	128	147	.171	.206
084	091	100	110	.122	137	157	.183	219
090	097	106	116	129	146	166	194	.233
095	.103	112	123	137	154	.176	.206	
100	.108	118	130	145	163	186	.217	
105	114	125	137	152	171	196	.228	
111	120	131	144	160	180	.206	.240	
.116	126	137	151	167	188	.215	.251	
.121	131	143	158	175	197	.225	.263	
126	137	.149	164	183	.206	.235		
132	143	156	.171	190	.214	.245		
137	148	162	178	198	.223	.255		
142	.154	168	185	205	231			
148	160	.174	192	.213	.240			
153	165	181	199	.221	.248			
.158	171	187	.206	.228				
.163	177	193	.212	.236				
169	.183	.199	.219	.244				

ordinary garments but is useful for some grades of felts. A fiber content of 5 per cent is the minimum amount required in producing a practical fabric such as a soft fleece It is important to note that this fiber content range of 20 to 5 per cent shows that fabrics of the same weight may vary in thickness by 400 per cent

The following examples illustrate the use of Table 20

1. What is the percentage air volume of a 12 ounce worsted suiting 075 inch thick?

Ans From 12 in the left hand column follow horizontally to the thickness of .075. Since 075 is in the column headed 89, this fabric contains 89 per cent air.

2 What is the thickness of a 16 ounce fleece containing 95 per cent air?

Ans From 16 in the left hand column follow horizontally to the column headed 95 per cent air and read 219 inch thickness

3 What is the weight of a doeskin 092 inch thick containing 80 per cent air?

Ans Find the 092 inch thickness in the column headed 80 per cent air, then follow to the fabric weight column on the left and read 27 ounces.

Combining the information in the above table with the warmth curve, Fig 28, it is seen that it is possible to obtain equal warmth with two fabrics of entirely different character For example, a well napped 16 ounce fleece coating, containing 95 per cent air was found to be just as warm as a 32 ounce overcoating containing 90 per cent air, as they were both 219 inch thick Similarly, a 27 ounce doeskin containing 80 per cent air gave no more insulation than a 10 ounce flannel containing 92 5 per cent air, as they were both .092 inch thick Of course, there is a great difference in the serviceability of these fabrics

TABLE 21

WEIGHT AND THICKNESS RANGE OF WOOL APPAREL FABRICS

Use	*Oz /linear yard—56"*	*Weight oz /sq yd*	*Thickness 005 lb /in*
Ladieswear			
Dress material	6—9	4—6	020—035
Suiting	8 5—12	5 5—8	030—070
Coating	12—18	8—12	050—250
Menswear			
Tropical worsted	8—10	5—6 5	025—035
Suiting & panting (Summer)	8—12	5—7 5	030—070
Suiting, winter	12—16	7 5—10	050—090
Top coating	16—20	10—12 5	070—150
Overcoating	20—32	12 5—21	130—250

Table 21 lists the normal ranges of weight and thickness of the various types of wool apparel fabrics From the previously explained thickness-warmth relation it is obvious that the above mentioned 10 ounce flannel having a thickness of 092 inch is suitable for winter wear even though, according to its weight, it could be classified as a summer fabric, and is also suitable for wear without a coat in the spring

From a warmth angle, fabrics should be divided into thickness ranges rather than weight ranges as shown in Table 22

TABLE 22
THICKNESS RANGE OF WOOL APPAREL FABRICS

	Thickness in inches
Ladieswear	
Dress material	020—035
Suiting	025—040
Coating	040—250
Menswear	
Summer suiting and panting	025—040
Winter suiting	040—090
Top coating	070—125
Overcoating	125—250

The relationship of thickness and warmth discussed above holds for all normal climatic conditions However, there are additional factors which are necessary for maintaining the comfort and health of the body. There must be sufficient ventilation through the clothing to permit the escape of the perspiration evaporated from the skin When the amount of perspiration is greatly increased by severe exercise, the skin becomes wet, i e, the perspiration is sensible Under such conditions the clothing becomes moist by absorption of the perspiration

Hock, Sookne, and Harris in a study on the thermal property of moist fabrics state.

Practical experience has demonstrated that moist fabrics in contact with the body produce an unpleasant sensation commonly referred to as a "chilling effect" or a "clammy feel" The degree of the sensation varies with different fibers and fabrics, thus, on the basis of general experience, the merits of wool fabrics over similar cotton fabrics have long been recognized This is one of the reasons, for example, for the preference given to woolen underwear and other garments for use in cold climates under conditions where physical labor causes considerable perspiration It also accounts for the approval usually expressed for woolen bathing suits

The chilling effect or clamminess produced by moist fabrics in contact with the body was evaluated by measurement of the drop in temperature that ensues when the moist fabrics are placed on

an artificial skin surface, and by tests to measure the extent of contact between the fabrics and the surface. (See Fig 29.)

Fabrics of various fiber composition and construction gave an excellent correlation in these tests The extent of contact between the fabrics and the skin appears to be the significant factor. Tests show that those fabrics making the poorest contact cause the least chilling.

The results of these experiments show clearly the progressive improvement of the fabrics with respect to chilling as their wool content is increased, and also the superiority of certain types of construction which minimize the extent of contact of the fabrics with the skin From this point of view the desirability of wool fibers, which are highly crimped and possess long range elasticity, is apparent These properties permit a type of fabric construction which minimizes the extent of contact with the skin. In contrast, cotton exhibits considerable plasticity when wet and is less desirable from the same point of view. However, the results show that special types of construction, especially those which produce a napped or fuzzy surface, reduce appreciably the contact which even wet cotton fabrics make and thereby lessen the chilling effect

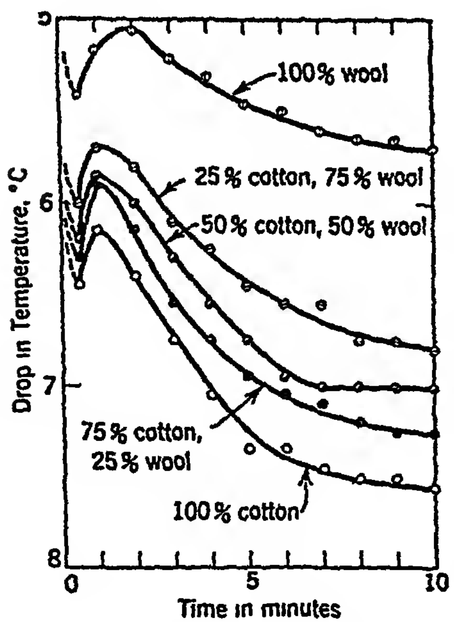


Fig 29 Thermal conductivity of various wet fabrics Relation between temperature drop and length of contact (*Hock, Sookne and Harris*)

Another factor which plays an important part in this whole question of warmth of textiles is the hygroscopic property of the material Cassie has shown that hygroscopic textiles can give a large measure of protection against sudden temperature changes at the skin A temperature change in the surrounding atmosphere begins to be propagated through textiles as if they had no hygroscopic property; but once the initial temperature is attained, the rate of change of textile temperature becomes very slow

Fig 30 shows a curve obtained experimentally for wool; air with

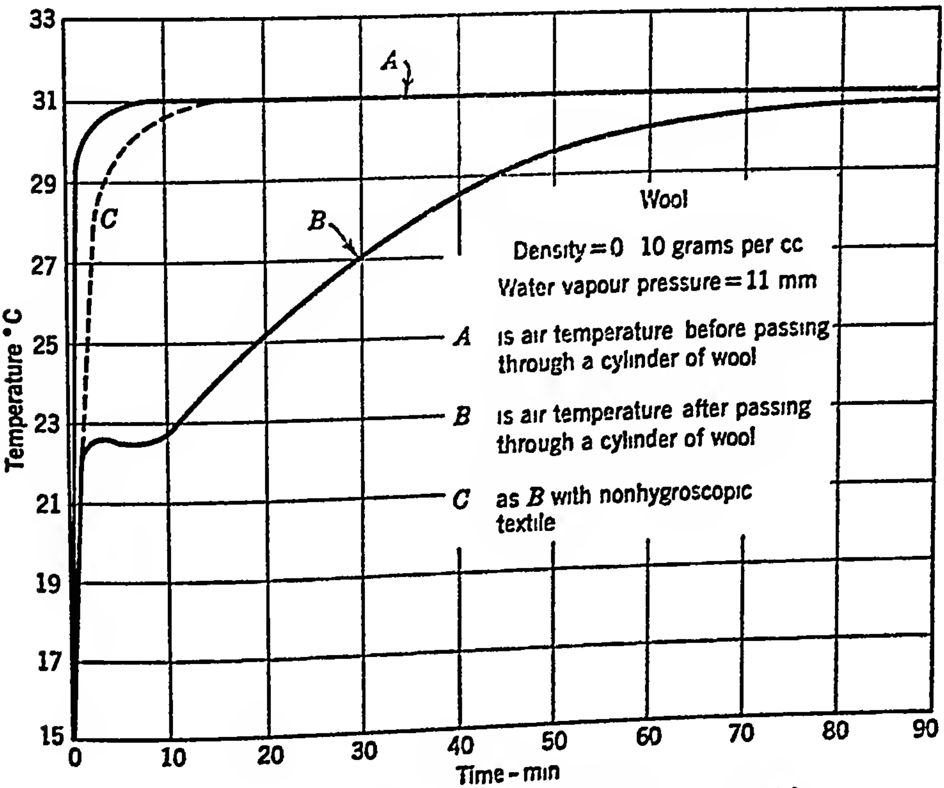


Fig 30 Thermal transmission of a wool fabric (*Cassie*)

a constant water vapor pressure and at 15°C (59°F.) was blown through a cylinder of wool until it was fully conditioned The temperature of the air entering the wool was then raised to 31°C (87 8°F) and curve *B* shows the rise in temperature with time at the center of the cylinder Rapid establishment of an initial temperature of 22 5°C. is clearly shown, and this is followed by the slow change to 31°C. If the wool was nonhygroscopic, its temperature would have increased according to curve *C*. The ratio of the times required to reach, say, 27°C. by following curves *B* and *C* is roughly 20·1.

Theory and experiment thus agree that hygroscopic textiles prevent sudden temperature changes from reaching the skin. The degree of protection increases as the standard deviation increases, and this factor is proportional to the rate of increase of regain with relative humidity. Roughly, hence, the greater the regain of a textile,

the greater its protective power, provided, of course, that the absorbed water does not give surface wetting of the fibers. Animal fibers are superior to others in this respect, they absorb more water than other textiles without losing their physical properties, in particular they show no surface wetting. They have long been recognized as supreme in avoiding sudden temperature changes at the skin, and there can be little doubt that this is due in a large measure to their high regains

The compressional resilience of wool is, indirectly, its most important thermal property. The ability of wool fabrics to maintain their thickness under nearly all conditions, thus entrapping a great volume of air, is attributable to the high resilience of wool fibers Even when wet, the fabric thickness is maintained and the contact area between the fabric and the skin remains low Thus, science has explained why wool is superior to all other fibers for comfort

Chapter 4

CHEMICAL NATURE AND PROPERTIES OF WOOL[1]

Composition of Wool

IN ITS chemical constitution raw wool is closely related to hair, horn, feathers, and other epidermal tissues A distinction should be made between the fiber proper and the wool as it comes from the fleece Wool in its raw state contains a variety of associated materials which are regarded by the user as impurities, though their presence is not necessarily a disadvantage, but a necessity for the well-being of the animal itself Because of (1) biological and genetic influences and (2) environment, including geographical, climatic, and nutritional factors, the quantities of these materials vary widely in different fleeces.

These impurities may be divided into three groups, namely, natural, acquired, and applied. The natural impurities, such as wool grease and suint, are secretions from the glands in the sheep's skin and are deposited on the wool fiber during its growth to protect it against mechanical and chemical influences while it remains on the sheep's back. The term applied to all of the extraneous material of animal origin adhering to the fleece, including both the suint and the wool grease, is *yolk* The acquired impurities are picked up by the animal from the pasture during its growth They may be mineral impurities, such as dust and dirt and earthy matter, or vegetable substances, such as straw, burrs, twigs, and grass The applied impurities are substances used in treatment against diseases and insect pests, such as dips, or substances put on the fleece for identifying purposes, such as tar or paint. The normal variations in impurities in various wools are seen in Table 1; the figures are expressed in percentages of the grease weight

[1] This chapter is largely taken from J Merritt Matthews and H R Mauersberger, *The Textile Fibers*, 5th Edition, by permission of the publishers, John Wiley & Sons, Inc., New York, 1947

TABLE 1

VARIATION IN PERCENTAGE OF FOREIGN IMPURITIES IN WOOLS

Type of Wool	*Yolk*	*Sand and Dirt*	*Vegetable Matter*	*Moisture*	*Wool Fiber*
Fine	20 to 50	5 to 40	0 5 to 2	8 to 12	20 to 50
Medium crossbred	15 to 30	5 to 20	1 to 5	8 to 12	40 to 60
Long wool	5 to 15	5 to 10	0 to 2	8 to 12	60 to 80
Carpet wool	5 to 15	5 to 20	0 5 to 2	8 to 12	60 to 80
Hairs	2 to 10	5 to 20	0 to 1	8 to 12	60 to 80

Wool Fat, Wool Grease, Wool Wax

These three terms, being substantially synonymous, are used to describe the "fatty" products obtained from wool. However, the fatty secretion in wool is, strictly speaking, a wax rather than a fat, since it contains no glycerin in combination with the fatty acids Yet, wool wax in many of its chemical and physical properties differs from other waxes Many of its constituent alcohols and acids are not only unusual and complex, but also are not found in other waxes Although wool wax cannot be used, therefore, as a substitute for other waxes, it has almost unlimited actual and potential uses of its own

The purified form of wool wax, known as lanolin, is especially valuable because of its unique similarity to the compounds exuded by the glands of the human skin As an emollient lanolin is unsurpassed

Lanolin is, for the most part, a complex mixture of complicated organic compounds known as steroid esters, the chemical nature of which is not yet fully understood The Botany Worsted Mills' research laboratory has reported that the alcoholic portion of lanolin, which can be obtained by splitting the esters; comprises about 40 per cent by weight of the total, while the fatty acid portion from the same ester splitting, constitutes the balance of about 60 per cent. About 14 to 16 per cent of the total weight of the lanolin consists of cholesterol, $C_{27}H_{45}OH$ Of this, 1 to 2 per cent is present in the free state, the remainder occurring as an ester' Analytical and physical data for wool wax are given in Table 2

The principal esters found in lanolin may be divided into three classes: the sterols, including cholesterol, meta-cholesterol, and isocholesterol, the triterpene alcohols, agnosterol and lanasterol and

normal aliphatic wax alcohols, such as cetyl and ceryl alcohols. These alcoholic substances exist both in the free state and chemically combined in the form of esters of numerous fatty acids, thirty-two of which have thus far been identified Each class of alcohols comprises about one-third of the total unsaponifiable matter or alcohols of the wax.

TABLE 2

ANALYTICAL AND PHYSICAL DATA FOR WOOL WAX

Characteristic	*Wool Wax*
Ash content, per cent	0 4–0 11
Acid value, per cent	0 4–2 0
Iodine value (Wijs)	19 8–30.0
Saponification value	97
Hydrocarbons, per cent	Nil
Unsaponifiable matter, per cent	50
Free cholesterol, per cent	3 0–4 5
Combined cholesterol, per cent	15 3
Melting point, °C	37–38
Specific gravity	0 944–0 947/15 5°C.
Refractive index	1.480/40°C

Source Gillespie, D T C, *Report T 3*, Commonwealth of Australia, Council for Scientific and Industrial Research Information Service, February, 1946

TABLE 3

CORRELATION BETWEEN QUALITY OF WOOL AND GREASE CONTENT

Quality	*Wool Fat (per cent)*
Fine (70s)	17 4
½ Blood (60s)	12 7
(58s)	10 5
⅜ Blood (56s)	9 8
¼ Blood (48s)	8 6

Source · Veitch, F P, and Benedict, L C, Wool Scouring Waste Liquors, Composition and Disposal Trans Am Inst Chem Eng 1925, June, p 3 22

Owing to the recent recognition of their effect on human metabolism, the importance of the sterols, including cholesterol, ergosterol or pro-vitamin D_2, the sex hormones, digitalis glucosides, and the saponins, has increased Consequently, the importance of wool wax has also become greater, since although cholesterol, the best known of

the sterols, occurs in most animal fats, nowhere has it been found in such large quantities as in wool wax

There is a definite correlation between wool quality and grease content, that is, the finer the wool, the higher is the grease content. This relationship can be seen in Table 3

As shown in Table 1, the percentage of yolk varies widely in fleeces of various breeds of sheep and even in sheep of the same breed Not only does the percentage of yolk vary, but also the composition of the wool wax as can be seen from Marston's analytical data on wool fats from Australian merino given in Table 4.

TABLE 4

VARIATION IN WOOL FATS FROM AUSTRALIAN MERINO WOOL

Fat in Wool Sample (per cent)	*Saponification Value*	*Iodine Value*	*Unsaponifiable Matter (per cent)*	*Free Cholesterol (per cent)*	*Total Cholesterol (per cent)*
10 to 20	92 to 107	16 5 to 19	21 to 27	3 5 to 7 0	7 5 to 16 0

Lifschutz was the first to show that the amount of the wax and the composition of the wax vary even within the individual staple The composition of the wax obtained from the tippy portion of the staple was very different from that of the wool wax taken as a whole (Table 5). The surface fat contains a much larger proportion of fatty acids and soaps; it also contains oxycholesterol in place of the isocholesterol present in fat near the roots. He sug-

TABLE 5

VARIATION OF WOOL GREASE FROM ROOT AND TIP PARTS

	South American Crossbred Wool		*Montevideo Merino Wool*		*Australian Merino Wool*	
	Roots	*Tips*	*Roots*	*Tips*	*Roots*	*Tips*
Fat content per cent	9 20	4 30	22 60	19.50	24.27	14 21
Acid no of fat extracted	15 68	25.70	2 24	14.56	almost neutral	17 92
Acid no after saponification	28 00	50 40	11 76	27 44	7 28	28 00
Free cholesterol	Traces	—	Traces	Traces	Large amount	Traces
Free isocholesterol	Large amount	—	Large amount	Traces	Large amount	Traces
Free oxycholesterol	—	Large amount	—	Large amount	Traces	Large amount

gested that the changes are brought about by hydrolysis and oxidation under the influences of moisture, light and air

The variability of the amount of wax in the wool of various breeds of sheep is accompanied by a similar variation in the amount of suint which ranges from 2 to 15 per cent As the amount of wax increases, the amount of suint also increases. Wright determined the amount of suint in New Zealand wools as shown in Table 6.

TABLE 6

SUINT IN NEW ZEALAND WOOLS

	Greasy Wool, Per cent
¾ Bred	12.72
½ Bred	10.30
Greasy Leicester	7.81
Lincoln	2.26

Ash in Wool

Besides the mineral matter existing in the soluble suint, there is a small amount of mineral matter which appears to be an essential constituent of the fiber itself It is left as an ash when scoured wool is ignited It amounts to about 0.5 per cent and consists of the alkaline sulfates, the majority being soluble in water. Bowman shows a typical composition of the ash of Lincoln wool in Table 7

TABLE 7

PER CENT COMPOSITION OF THE ASH OF LINCOLN WOOLS

Potassium oxide	31.1	Silica	5.8
Sodium oxide	8.2	Sulfuric anhydride	20.5
Calcium oxide	16.9	Carbonic acid	4.2
Aluminum oxide } Ferric oxide }	12.3	Phosphoric acid	Trace
		Chlorine	Trace

Nature of the Protein Keratin

The wool fiber is composed of animal tissues and is classed as a protein called keratin Proteins are very complicated chemical compounds and keratin is no exception Wool fiber has been found to consist of five chemical elements—carbon, hydrogen, oxygen, nitro-

gen and sulfur Sulfur is distinctly characteristic of wool and all hair fibers. As its constituents are not rigidly constant in their proportion, no definite chemical formula can be assigned to wool Its chemical composition is as shown in Table 8

TABLE 8

CHEMICAL COMPOSITION OF WOOL

Elements	*Per cent*
Carbon	50
Oxygen	22 to 25
Nitrogen	16 to 17
Hydrogen	7
Sulfur	3 to 4

The wool fiber as a whole does not appear as a homogeneous chemical compound, but is composed of several chemically distinct substances, a fact substantiated by recent research by Geiger, who states that the protein scale contains more sulfur than do the more digestible proteins of the cortex (Table 9)

TABLE 9

COMPOSITION OF UNTREATED WOOL AND WOOL SCALES
(In per cent)

Constituents	*Untreated Wool*	*Wool Scales*	
		Analytical Value	*Corrected Value**
Sulfur	3 50	4 83	5 42
Cystine	12.2	18 1†	20 3†
Nitrogen	16 67	13 53	15 17
Arginine	8 6	4 3	4 8
Tyrosine	6 1	3 0	3 3
Serine	9 5	9 9	11 2
Ethyl groups	0 0	4 0	...
Ash	0.2	4 1	...
Lipid	..	2 7	.

* Corrected for the presence of ethyl groups and bound lipid
† Calculated from the sulfur content.

Keratin is of amphoteric nature, exhibiting acid as well as basic properties with the basic predominant Through hydrolysis it decomposes into various amino acids, as Harris shows in Table 10

TABLE 10

AMINO ACID COMPOSITION OF WOOL

Amino Acids	*Percentage present in Wool*	*Grams of Residue per 100 Grams of Wool*	*Grams of Side-chain per 100 Grams of Wool*
Glycine	6 5	4 94	0 09
Alanine	4 4	3 52	0 74
Serine	9 41	7 80	2 76
Proline	6 75	5 69	2 46
Valine	4 72	3 99	1.73
Threonine	6 76	5 74	2.59
Cystine	12 72*	10 83	4 89
Leucine isomers	11 3	9 75	4 92
Aspartic acid	7 27	6.28	3.22
Lysine	3.3	2 89	1 63
Glutamic acid	15.27	13 40	7.58
Methionine	0 71	0 62	0 36
Histidine	0 7	0 62	0.37
Hydroxylysine	0.21	0 19	0 11
Phenylalanine	3 75	3 34	2 07
Arginine	10 4	9 33	5 97
Tyrosine	5 8	5.23	3 43
Tryptophane	0 7	0 64	0 45
Total	110 67	94 80	45 37
Ammonia N	1 18	—0 30	—0.30
Total, corrected for ammonia N		94 50	45 07

* Based on 3 55 per cent total sulfur, subtracting methionine sulfur

Harris, Mizell, and Fourt have summarized present knowledge of the molecular structure of wool and the factors which are responsible for its mechanical properties Proteins are polycondensation products in which the different amino acids are linked together to form the polypeptide chain, shown in the following scheme

```
                          R                                   R
                          |                                   |
—HN—CH—CO—HN—CH—CO—HN—CH—CO—HN—CH—CO
       |                                  |
       R                                  R
```

The mechanical properties of such chains can be considered, in general, to depend on the following four factors:

1. They exhibit great flexibility. This enables the protein molecule

to assume a great number of possible configurations which could be either of the folded or spiral type. The importance of this molecular flexibility was first recognized by Astbury and Woods, who in their earlier work on wool preferred a rather specific type of fold for the molecules of the fiber in the unstretched state, which they referred to as the α-keratin configuration The long-range extensibility of wool was ascribed to the opening of these folds into the more nearly straight chain configuration known as the β-keratin form. The original α-keratin configuration has been shown to be untenable by Neurath, and a new type of fold has now been proposed by Astbury and Bell Such structures have been suggested on the basis of the x-ray data and should accordingly be found principally in the "crystalline" regions of the fiber. Since these regions account for only a relatively small proportion of the total wool fiber as indicated by the x-ray diffraction patterns, it appears that one may assume a more or less random type of folding in the "amorphous" regions which make up the bulk of the fiber. That a variety of configurations can exist is readily demonstrated by the construction of molecular scale models of polypeptide chains.

2 They possess a large number of the highly polar peptide linkages which give rise to inter- and intra-molecular hydrogen bonding

3. They contain relatively large side chains (R groups in the polypeptide chain), which prevent close packing of the protein molecules and thus decrease the extent to which hydrogen bonding can occur. In wool nearly all of the constituent amino acids are of the type having large side chains, as shown by the data in Table 10 From these data it can be estimated that close to 50 per cent of the weight of wool is in the side chains They exhibit association forces other than those contributed by hydrogen bonds, namely, the presence of covalent disulfide cross-links between the molecular chains

4 Cystine (as first suggested by Astbury and Street) is responsible for a considerable amount of covalent cross-linking in the fiber More recently, new chemical evidence has been offered which supports the original conclusion of Astbury and Street Wool may thus be considered a network of polypeptide chains linked together by the disulfide groups of the amino acid, cystine. Such a concept suggests that the role of cystine in wool is an important one and, indeed, it has been shown that many of the chemical, physical and biological properties of wool protein are dependent on the presence of these cross-links.

Structural Formula of Wool

Astbury and Speakman suggest that the structure of the wool fiber, reduced to its simplest terms, consists of long peptide chains bridged by cystine and salt linkages as shown in its structural formula, Fig. 1.

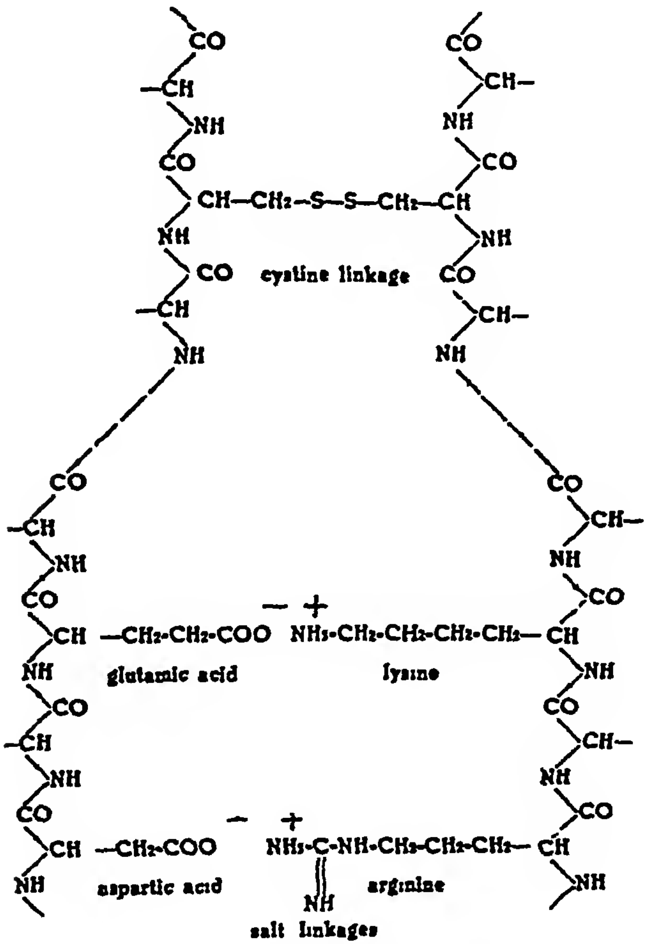


Fig 1 Structural formula for wool (Astbury and Speakman.)

This structural arrangement accounts for much of the chemical stability of the wool molecules which make up the fiber. However,

it has been found that any reagent which will alter the state of this disulfide group in the cystine linkage will alter or destroy the physical structure of the fiber as a whole. In general, these groups are susceptible to attack by oxidizing and reducing agents, light and alkalis. Strong oxidization may result in practically no change in the outward appearance of the wool, yet the incipient damage may be so great as to render the wool nearly worthless This knowledge is utilized in the practical control of bleaching and chlorination From the standpoint of dyeing and carbonizing, researches have further increased knowledge of the amphoteric nature, i e, the acid and basic properties, of the wool fiber.

Nitrogen in Wool

The presence of nitrogen in wool becomes evident by simply burning a small sample of the fiber. The characteristic empyreumatic odor of nitrogenous animal matter is then observed Heating wool in a small combustion test tube shows that ammonia, which can be tested for, is among the gaseous products evolved

Sulfur in Wool

The sulfur in wool is present in the form of the amino acid, cystine, which occurs naturally to a greater or lesser extent in almost all protein foods and is an essential factor in body growth The possible significance of sulfur in the sheep diet, and its influence on the composition and properties of wool, was first pointed out by King and has been investigated by various workers. Sulfur is essential to the formation of wool substance, and a deficiency will result in an abnormal fleece

Marston and Robertson, arguing from their conclusion that wool keratin has a constant percentage of sulfur, anticipated no alteration in chemical composition as a result of an enriched cystine diet, but an increase in the total fleece weight, proportionate to the extra amount of sulfur utilized by the animal for wool production

Experimental verification of improved quality and weight of fleece through cystine feeding, especially in the form of wool hydrolysate, is reported by the Division of Animal Nutrition, Adelaide Beadles, Braman, and Mitchell find that in rats an increased hair growth results from a cystine-rich diet. On the other hand, the evidence advanced by Barritt and King that the sulfur content in wool keratin is far from constant (as shown in Table 11) has been further strengthened by their more recent investigations with Pickard on Angora rabbit wool.

TABLE 11

SULFUR CONTENT OF VARIOUS WOOLS

Type of Wool	*Per Cent Sulfur on Dry Weight*	*Type of Wool*	*Per Cent Sulfur on Dry Weight*
Cape merino	4.00	Turkey mohair (fine)	3.36
Welsh Mountain	3.97	Devon lamb	3.34
Blackface (fine)	3.82	Fine Ripon	3.34
Australian merino 100s	3.76	Blackface (coarse)	3.33
Peruvian (1924)	3.75	Blackface (kempy)	3.24
South African merino	3.67	New Zealand crossbred	3.22
Australian stud ram	3.56	Lincoln (white)	3.10
New Zealand 50s	3.47	Turkey mohair (coarse)	3.03

Harris and his coworkers found similar large variations in the sulfur content of fur fibers and the various specialty hair fibers. Their results reported in Table 12 comprise the average of three tests. All samples were solvent cleaned.

TABLE 12

SULFUR AND NITROGEN CONTENT OF VARIOUS ANIMAL FIBERS

(Dry weight)

Class	*Type*	*Sulfur (per cent)*	*Nitrogen (per cent)*
Fur fibers	Raccoon	5.78	15.55
	Muskrat	4.68	15.95
	Russian rabbit	3.84	15.87
Specialty hairs	Alpaca	4.17	16.30
	Vicuña	4.10	16.26
	Turkey mohair	3.58	16.40
	Texas mohair	2.92	16.51
	Camel's hair	3.41	16.48
	Cashmere	3.39	16.42
Wools	Domestic wool	3.50	16.41
	Cordova carpet	3.32	16.29
	Egyptian carpet fawn	3.25	16.10

Effect of Sunlight on Wool

The wool fiber is affected by sunlight to some extent during its growth. The photochemical decomposition in "weathering" takes

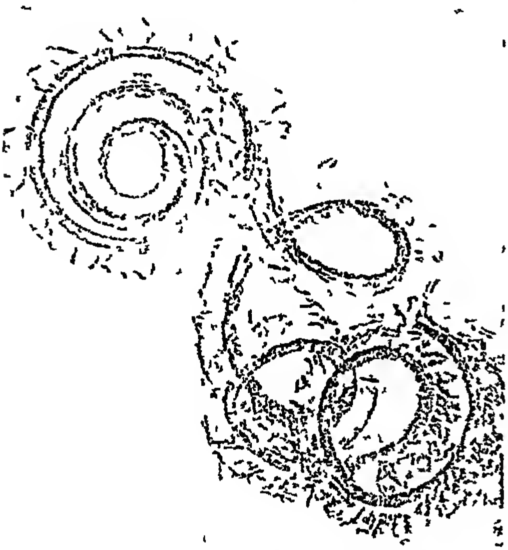


Fig 2 Sunlight-damaged wool fiber after treatment with 0 1*N* NaOH

place on the back of the animal, which is exposed to light. It results in a yellowish brown discoloration accompanied by a harsh feel in the upper tips of the staples on the back and the flanks of the animal It is caused by the formation of sulfuric acid from the sulfur present in the wool The exposed fibers become brittle and weak and also become sensitive to alkalies, which in the case of caustic soda causes a strong swelling effect, i e, curling of hairs. (Fig 2.) Von Bergen found that the extent of the swelling is, up to a certain limit, in direct proportion to the length of exposure to sunlight

The relation between the amount of sunlight and the swelling with 0 1*N* NaOH is shown by the curves in Fig. 3 The damage done to raw wool, while still on the back of the sheep, is proved by the data given in Table 13

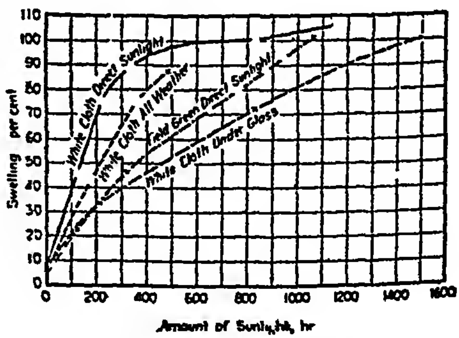


Fig 3 Relation between amount of sunlight, exposure time and swelling with 0 1*N* NaOH on wool from exposed woolen cloth (von Bergen)

The photochemical decomposition of wool has been further investigated by Smith and Harris The deterioration, as evidenced by the decrease in cystine content and the increase in alkali-solubility, ammonia nitrogen and sulfate sulfur, is accelerated by acids and decelerated by alkalies The extent to which wool is degraded during irradiation is directly proportional to the decrease in cystine content and to the increase in alkali-solubility. The sulfur content

TABLE 13

EFFECTS OF SUNLIGHT ON RAW WOOL

Origin	Place on Animal	End of Staple Width, Unswollen (microns)	Width Swollen (microns)	Swelling (per cent)
Australian wool	back	23 08	44 46	92 63
	belly	27 27	29 88	9 6
Virginia wool	back	35 06	45.23	29 00
	belly	42 08	44 37	5 44
Württemberg wool	back	33 49	43 42	29 65
	flanks	33 00	35 8	8 5
	belly	27 7	29 3	5 8
Swiss mountain wool	back	28 57	50 69	77 4

of untreated and acid-treated wool decreased during irradiation The data suggest that a portion of the sulfur in wool is converted to hydrogen sulfide, some of which is subsequently oxidized to sulfuric acid

Action of Heat on Wool

When wool is heated in dry air at 212° to 220° F (100° to 105° C.) over a long period it loses its moisture and the fiber becomes harsh and loses strength If returned to moist air, it rapidly reabsorbs moisture and regains more or less its softness and strength If 212° F. is exceeded for any length of time the wool will decompose, will acquire a yellow color and ammonia and hydrogen sulfide will evolve

Studies made by Raynes show that H_2S and NH_3 are evolved even at 212° F. when the heating is prolonged over 48 hours The most recent studies made by Stirm and Rouette show the effect of temperature, time, humidity and pH value on the decomposition of wool The amounts of NH_3 and H_2S evolved by the process were taken as a measure of the decomposition The amounts of NH_3 and H_2S increased rapidly when the temperature rose over 100° C and when the humidity increased When the wool was treated with alkali more NH_3 and H_2S evolved, showing increased decomposition

Wiegerink determined the effects of drying under selected conditions of temperature and atmospheric humidity on certain properties of worsted yarns and found that, for clothing and carpet wools, the

effect of heat is less than the effect of humidity. This is particularly true of carpet wool, which shows the greatest deterioration at a high humidity Carpet wool is less resistant to heat and humidity than clothing wool.

Wool when burned gives off a characteristic odor, similar to that of burning hair or feathers, due chiefly to the presence of nitrogen in the compound. When removed from the flame, wool will stop burning and each single fiber exhibits a black knob or charred globule on its end Wool is, therefore, fire resistant The vapor coming off during the burning process has an alkaline reaction, turning moist red litmus paper blue.

Action of Cold on Wool

The influence of a low temperature on wool has become of importance since the introduction of the frosted wool process The wool is treated at temperatures from 40° to 60° below 0° F. The wool is still pliable, only vegetable and fatty matter being frozen, enabling it to be separated from the wool by mechanical action Low temperatures have no chemical effect on the fiber.

Effects of Water and Steam

Water and steam, respectively moisture and heat, are the basis of many finishing processes When wool is exposed to water, cold or hot, and steam, with or without tension, the behavior of the wool substance shows important characteristics As a plastic substance, similar to horn, it will change its shape and its affinity toward dyes Wool is insoluble in water under ordinary conditions. Boiled for two hours in distilled water, the wool loses approximately a quarter of 1 per cent of its weight. Humfield, Elmquist, and Kettering reported a 29 per cent decrease in strength of a serge fabric through twelve hours' boiling in water In cold and warm water the fiber swells or increases in size approximately 10 per cent (chemically damaged wool may swell 20 per cent or more), but, on drying, the fiber returns to its former diameter. With water under pressure at temperatures above 250° F., wool dissolves In dyeing processes the boiling time influences the breaking strength

Steam (212° F.) when applied for a short time has no damaging effect, but extended periods of application attack the wool to a point where it loses all its strength. Elliot reports a wool fabric losing 5 per cent of its average dry breaking strength after twenty-five hours in the dry heat of an autoclave at 100° C but 75 per cent after the same treatment in moist heat, at 120° C the corre-

sponding losses were 16 per cent and 100 per cent. Browning of wool has been described by Fort as progressive with duration of steaming and is greater at 100° C. than that brought about by boiling water or dry heat. A wool steamed at 99° to 100° C. for 3, 6, 12, 24, 36, 48, and 60 hours was observed by Scheurer to lose 18, 23, 28, 40, 50, 64, and 74 per cent of its original strength.

Walde, Barr, and Edgar showed that the degradation of wool by steam increases with increasing time or pressure. The mechanical failure is more rapid than loss of weight, nitrogen, or sulfur, indicating a breakdown of fibrous structure preceding the formation of soluble degradation products, as shown in Tables 14 and 15.

TABLE 14

EFFECT OF STEAM AT VARIOUS PRESSURES ON WOOL FABRIC

(Time, one hour)

		Residual Keratin				
Steam Pressure (lb per sq in.)	*Temperature (°C.)*	*Weight (per cent of wool)*	*Nitrogen (per cent of wool)*	*Sulfur (per cent of wool)*	*Breaking Strength of Wet Warp (lb per in)*	*Elongation at Breaking Load (per cent)*
0	100 0	99 4	16 44	3 88	13	50
10	115.2	99 0	16 44	3 74	11	55
15	121 0	99 1	16.25	3 75	8	40
20	126 0	98 9	16 36	3 75	2	49
30	134 5	98 7	16 13	3 68	<1	..
40	141.5	93 9	15 72	3 33	<1	..

TABLE 15

EFFECT OF STEAMING TIME ON WOOL FABRIC

(Steam pressure 10 lb , temperature 115.2° C)

	Residual Keratin				
Time (hours)	*Weight (per cent of wool)*	*Nitrogen (per cent of wool)*	*Sulfur (per cent of wool)*	*Breaking Strength of Wet Warp (lb per in)*	*Elongation at Breaking Load (per cent)*
0	100 0	16 49	3 99	15	56
1	99 0	16 44	3.74	11	55
3	99 1	16 39	3 76	7	42
5	98 6	15 80	3 69	2	47

Humfield, Elmquist, and Kettering reported that three intermittent steamings of half an hour each at 100° C of serge fabrics produced 9 3 per cent loss in strength index, while four steamings increased the loss to 14 per cent In autoclaving the same fabric dry and wet for half an hour at 15-pounds steam pressure, the loss in the strength index was 4.6 per cent for the dry and 31 2 per cent for the wet, which indicates that the effect of dry heat is less damaging than wet steam.

Plastic Properties of Wool

Concerning plastic properties, the following principles govern the behavior of wool· first, if wool in the dry state is deformed by imposing some strain, for example, in the process of spinning, the fiber will tend to recover its original form when the humidity is increased This may be brought about by wetting out or exposing to a moist atmosphere like steaming Second, wool loses its rigidity almost completely, i.e, becomes plastic, in boiling water. Third, the behavior of the wool under the influence of moisture and heat is greatly affected by time and temperature The plasticity of wool increases rapidly with a rise of temperature and may be so great that stretched fibers, after steaming, for example, are no longer able to return to their original length when released in cold water In other words, they take a "permanent set."

This is the basis of finishing processes such as "crabbing" and "blowing" The conditions for the realization of a permanent set were determined by Speakman, and a discovery was made that the "set" imposed at any one temperature is permanent only to water at a lower temperature than that at which it was imposed This

TABLE 16

LENGTHS OF COTSWOLD WOOL CELLS FROM FIBERS SET IN STEAM AT VARIOUS EXTENSIONS

Extension of Fibers (per cent)	*No of Cells*	*Mean Length, (microns)*	*Standard Deviation (microns)*	*Extension of Cells (per cent)*
10 0	224	114	25 4	5
15 0	202	118	25 4	8
19 5	130	121	26 4	11
20 0	246	120	26 4	10
30.5	203	131 5	27.0	21
40 0	216	144 5	27 7	33
53 0	203	155	30 4	42

discovery has far-reaching consequences in connection with wool finishing processes, particularly London shrinking, tentering, and the production of crepe effects in wool goods Woods found that the temporary set developed in fibers when stretched and steamed is not due to the intercellular material but is a property possessed by the cortical cells as units A direct relationship exists between the extension of steam-set fibers and the extension of the cortical cells, as shown in Table 16, where all fibers were measured in water and the normal length of wet cells was 109 microns.

The elongated cells recover only partially when they are boiled in water, and the permanent set remaining is of the same order as that which the fibers would have shown Permanent set is thus also a property of the cells themselves

Cotswold wool fibers which have been relaxed in dilute caustic soda can also be disintegrated into cells which recover during the process to something less than the normal length These relaxed cells can be supercontracted still further by boiling water In this way cells of about half the normal length can be obtained, their crystalline part shows itself in the β-form, just as does that of highly supercontracted fibers

By the combined action of lateral pressure and steam the cells from normal fibers may be compounded into coherent transparent sheets which are elastic in cold water for extensions up to about 50 per cent and are extensible in steam or caustic soda by twice this amount These sheets can be relaxed, set and supercontracted in the same way as fibers and their tensile strength in water is about 25 per cent of that of fibers This suggests that the coherence developed during the steam treatment is similar to the development of permanent set in a stretched fiber

Isoelectric and Isoionic Points of Wool

On the significance of these two points Harris gives the following explanation·

It has generally been assumed that the isoelectric point of wool represents the point of maximum stability of the fiber Although the isoelectric points of some proteins appear to be close to the points of maximum stability, they are not necessarily the same Actually, it is possible for the stability region of a protein to be far from the isoelectric point Whether the point of maximum stability will be at or near the isoelectric point will depend upon the reactivity of specific linkages in the molecules For example, assume that a protein containing disulfide linkages from the amino acid cystine has an isoelectric point in the alkaline region as a consequence of a high content of either lysine or arginine In view of the known instability of disulfides in

even weakly alkaline solutions, it is very unlikely that the point of maximum stability of such a substance would be located near its isoelectric point

The concept of isoelectric and isoionic points can be utilized in practical wool processing Since the isoionic point involves only the acidic and basic properties of the fiber, it should be considered in studying such wool processes as are related to these properties Dyeing with soluble dyes, felting, and removal of ash constituents from the fiber are processes that probably fall within this category In addition, the swelling and tensile properties of wet fibers are a function of the state of their acidic and basic groups

The isoelectric point, on the other hand, is concerned primarily with the total net surface charge and must only be considered in relation to processes involving either the removal or deposition of materials on the surface of the fiber In other words, it would play an important part in such processes as scouring and finishing Scouring is facilitated when the charge on a fiber and the charge on the material being removed from the fiber are the same and therefore tend to repel each other For example, dirt particles and particles of most inert substances carry negative charges Obviously then, such macroscopic particles are best removed from fibers which also have a large net negative charge Similarly, the deposition of certain finishing materials on fibers or fabrics is best accomplished when the charges on the fibers and material to be deposited are of opposite sign Although the dyeing problem is undoubtedly more complicated, it is probable that dyeing with colloidal dyes is related to the isoelectric point

In acetate buffers, the isoelectric point of wool scales and cortical cells was found to be at *p*H 4 5 Samples of ground or powdered wool show an isoelectric point at *p*H 4.2 The isoionic point of commencement of combination of the wool fiber with acid, according to Speakman, is around *p*H 4 8 and *p*H 5 0, which is in close agreement with Elod's figure of *p*H 5 0 Harris states that in the absence of salt the *p*H at zero combination is in the range 4 7 to 5 1 Wool does not combine with any significant amount of alkali below *p*H 10 and for general purposes may be regarded as possessing an isoionic range from *p*H 5 to 10

Acid and Basic Nature of Wool

In its chemical reactions wool exhibits the characteristics of both an acid and a base The reason for this amphoteric nature lies in its composition—it contains various amino acids

The titration curve reflects best the acidic and basic characteristics of the wool fiber and affords a proof of the real existence of salt linkages within the fiber The best known studies were made by Speakman and Stott, Speakman and McMahon, and Steinhardt, Fugitt, and Harris. In analyzing the curves as shown in Figs 4 and 5 Harris and his collaborators came to the following conclusions.

The maximum acid-binding capacity of hydrochloric acid at 0° C., independent of ionic strength, is 0 82 millimole per gram; the maximum base-binding capacity of potassium hydroxide is greater than 0 78 millimole With salt absent, no appreciable binding of acid or base occurs in the *p*H interval 5 to 10, but the amount bound increases sharply as these limits are exceeded. When salt is present, the amount of acid or base bound changes with *p*H more gradually and there is no wide region in which combination fails to occur; the point of zero combination is sharply defined and is near *p*H 6 4 The positions of the titration curves with respect to the *p*H axis are different at every ionic strength. The differences are larger than can be attributed to the effect of salts on the dissociation of acids, thus, in dilute solutions an *n*-fold change in the total concentration of chloride ions produces a change almost as great as would be produced by a similar *n*-fold change in the concentration of hydrogen ions This approach to stoichiometric dependence of the acid bound

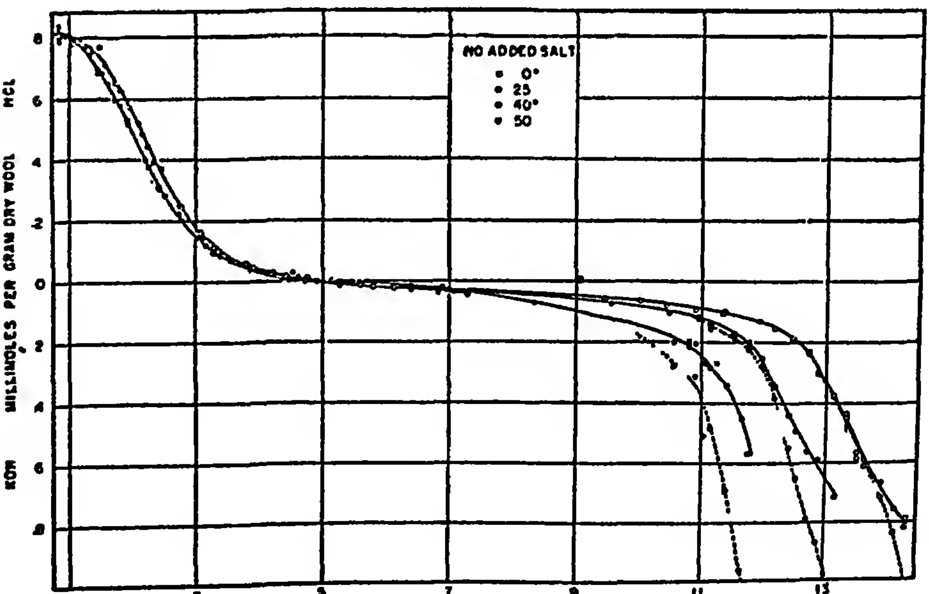


Fig 4 Combination of wool with hydrochloric acid and potassium hydroxide as a function of *p*H and temperature, in the absence of salt.
(*Steinhardt, Fugitt and Harris*)

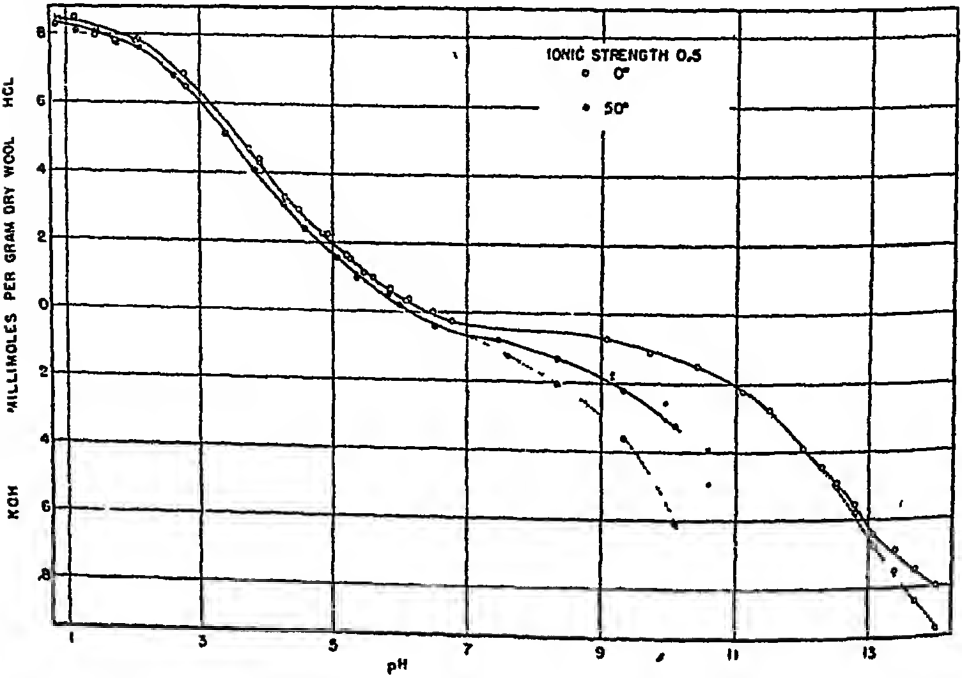


Fig 5 Combination of wool with hydrochloric acid and potassium hydroxide as a function of pH and temperature, at 0 5M ionic strength
(*Steinhardt, Fugitt and Harris*)

on the concentration of anions as well as of hydrogen ions accounts for the greater steepness of the titration curve when the source of both ions is the acid alone

The dependence of acid bound on anion concentration or base bound on concentration of cations shows that the positions of the curves with respect to the pH axis should, at high salt concentrations, approach a limit which should correspond to the titration curve of the same protein in the dissolved state. This is further supported by the fact that the data for wool agree very closely at high salt concentrations with those for a similar but soluble protein, egg albumin

The analysis of the composition of the titration curve in terms of the constituent diacidic and dibasic amino acids of wool leads to the conclusion that the binding of acid and base by wool occurs at the free carboxyl, imidazole, amino, and guanidino groups, but that no combination of base with the tyrosine hydroxyl group takes place in the pH range of this investigation

The data in Fig. 4 support the assumption made in accounting for previously reported titration measurements at 0° C, that the carboxyl and amino groups of wool in the uncombined state are completely ionized. Thus, changes in the *p*H coordinates at the titration curves brought about by changes in temperature are small in the *p*H range in which acid is combined, which indicates that combination with acid is equivalent to back-titration of the carboxyl groups, but are large in the *p*H range in which base is combined, which indicates that combination with base is equivalent to back-titration of amino groups.

The heats of dissociation calculated for the two kinds of groups, approximately 2500 and 14,000 calories, are in good agreement with values for these groups in comparable compounds and in soluble proteins The value obtained in the acid range also agrees with the results of calorimetric measurements on the combination of acid with wool

Approximately equal parts of the total heat changes in the acid range are associated with the dissociation of hydrogen ions and chloride ions from the fiber. An appreciable part of the total heat effect may be ascribed to a heat of transfer of the ions between the two phases of the heterogeneous titration system

Effect of Acids on Wool

The titration curve of wool shows that the action of acid begins at *p*H 5 and in hydrochloric acid is completed at *p*H 1 In hydrochloric acid solutions wool combines stoichiometrically not only with the hydrogen ions of the acid but with the chloride ions as well Hence, the specific affinities for wool of the anions of different strong acids vary considerably and therefore the positions of the titration curves of wool with respect to the *p*H axis vary by correspondingly large amounts, according to the acid used This has been well established by Speakman and Stott, and by Steinhardt, Fugitt, and Harris

The titration curves of strong acids (Fig 6) are S shaped and form a coherent family, near neighbors following a fairly parallel course If the position of each curve is characterized by the *p*H value at which half the maximum amount of acid (about 0 4 millimole per gram) is taken up, there is a difference of 2 *p*H units between the curves shown at the extremes of the series

The anion-wool associations for strong acids are fully reversible, and the wool in combining with acid suffers no permanent alteration until amounts which approach 0 8 millimole per gram are combined.

The curves for the acids of lower affinity are characterized by flattening in the neighborhood of 0.83 to 0.84 millimole per gram combined. This fairly well marked "maximum" corresponds closely to the primary amino content of the fibers. With acids of higher affinity, however, the curves show a definite increase in the slope, which represents a second step of acid combination. The amounts of acid bound at low pH in some of the acids are far in excess of 0.8 millimole per gram of wool. This increase in the acid-binding capacity is due to hydrolytic decomposition.

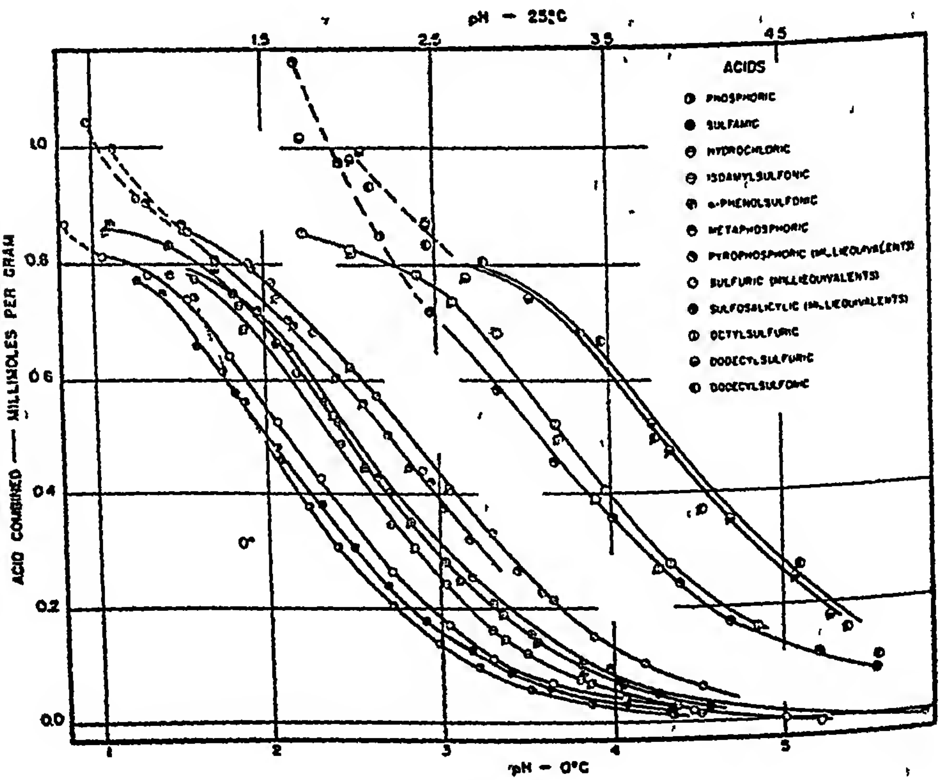


Fig. 6. Combination of wool protein with strong acids at 0° or 25°C. (*Steinhardt, Fugitt and Harris.*)

Note. The pH scale at the bottom of the figure applies to the data obtained at 0°C. The scale at the top of the figure refers to the data obtained at 25°C.

With hydrochloric acid, even with high concentrations, negligible amounts of ammonia at 0° C are found, whereas with acids of higher affinity ammonia is liberated more rapidly and the acid-binding capacity increases in direct relation to the amount of ammonia liberated With some acids this increase amounts to over 0 3 millimole per gram of wool However, where the hydrolysis of the peptide bonds leads to the formation of some insoluble decomposition products a real increase in acid-binding power is observed

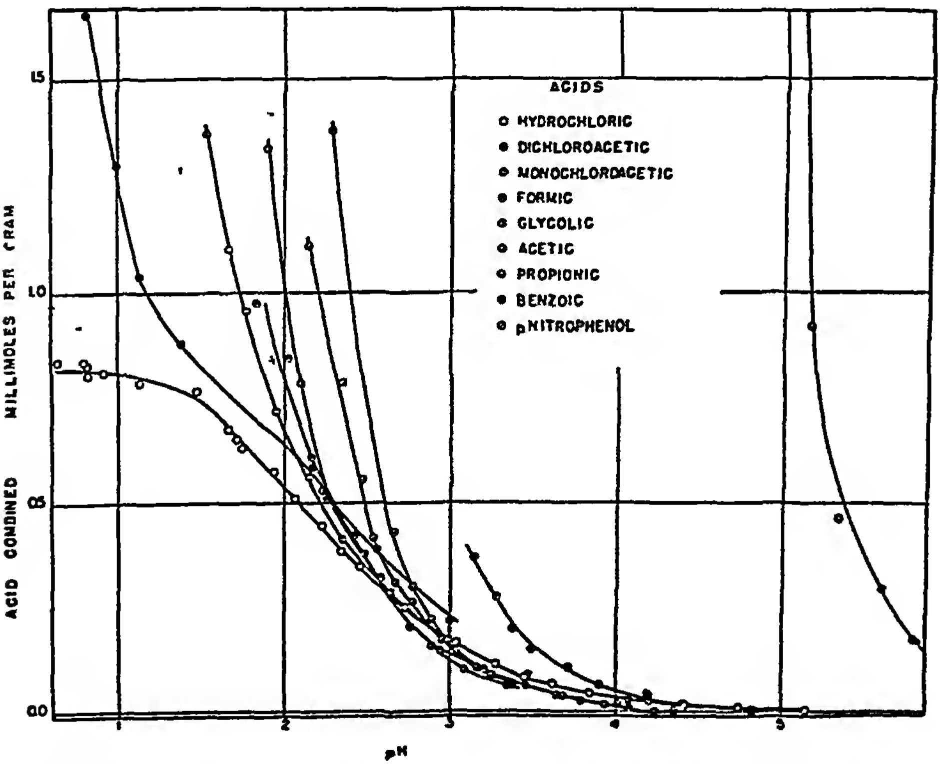


Fig 7 Combination of purified wool with weak acids at 0°C. The curve for hydrochloric acid is given for comparison (*Steinhardt, Fugitt and Harris*)

Weak Acids

The titration curves obtained with eight organic acids by Steinhardt, Fugitt, and Harris are compared in Fig. 7 with the curve of

hydrochloric acid This graphic comparison brings out clearly the principal difference between the behavior of strong and weak acids with respect to wool. Over a wide range of low concentrations, many of the acids are combined by wool at a given *p*H to about the extent that it combines with hydrochloric acid. The presence of undissociated acid at these concentrations is without appreciable effect. At higher concentrations, however, the amounts of weak acids which are combined increase more sharply than the amounts combined of hydrochloric acid, and, unlike the latter, give no indication of approaching a saturation value at about 0.8 millimole per gram Indeed, determinations have been made of amounts combined which are far beyond the upper limits of Fig. 7 (up to 4 millimoles per gram).

Most of the acids shown in Fig. 7 are organic acids of relatively low molecular weight and would be expected, if totally dissociated, to give titration curves of wool similar to the curve obtained with hydrochloric acid. If attention is confined to the lower portion of the curves obtained with acids of molecular weights below 80, it appears that this expectation is well founded. Marked departures from the curve for hydrochloric acid appear only at concentrations at which the amounts of undissociated acid become greater than about 0.01 mole. The increased uptake of weak acids which appears at high concentrations is a rough measure of the amounts of undissociated acid that have combined with the wool, possibly by solvating it in competition with water. In Table 17 are shown

TABLE 17

COMBINATION OF UNDISSOCIATED MONOCHLOROACETIC ACID WITH WOOL AT 0° C.

*p*H	*Acid Combined* * *(mmoles/g)*	*HCl Combined at Same pH (mmoles/g)*	*Difference (mmoles/g)*	*Total Acid (mmoles/liter)*	*Undissociated Acid* † *(mmoles/liter)*	*Excess Combination Divided by Concentration of Undissociated Acid*
1.36	2.08	0.79	1.29	0.971	0.937	1.4
1.52	1.39	0.77	0.62	0.477	0.455	1.2
1.66	1.12	0.71	0.41	0.282	0.265	1.5
1.76	0.97	0.66	0.31	0.184	0.070	1.5
1.95	0.73	0.59	0.14	0.0874	0.0769	1.8
2.15	0.580	0.504	0.076	0.0398	0.0332	2.3
2.35	0.431	0.403	0.028	0.0172	0.0132	2.1

* No corrections have been applied for the error in calculating the uptake of acid which is introduced or the absorption of water by the fibers.

† The values in this column are derived from the total acid present by utilizing Wright's value of the dissociation constant and applying the law of mass action. Since the proportion ionized is small, except in the more dilute solutions, little error is introduced by the neglect of activity coefficients.

data for monochloroacetic acid, which has been chosen as an example because the lower part of the curve of this acid coincides most closely with that for hydrochloric acid.

In Table 18 are summarized the relative affinities of undissociated acids for wool as calculated by the method shown in Table 17 Approximate values for a few cyclic compounds not represented in Fig. 7 are also included The range of the affinities of the undissociated acid for wool, as shown in Table 18, is approximately 300 to 1.

TABLE 18

AFFINITIES OF UNDISSOCIATED ACIDS FOR WOOL PROTEIN AT 0°C

Acids	*Partition Quotient*	*Acids*	*Partition Quotient*
Propionic	0 3	Benzoic	11
Acetic	0 4	*p*-Nitrophenol	20
Glycolic	0 6	2,4-Dinitrophenol	50
Formic	0 7	2,6-Dinitrophenol	60
Monochloroacetic	1 8	2,6-Dichloro-4-nitrophenol	100
Dichloroacetic	2	2,4,6-Trichlorophenol	100

Speakman and Stott stated that the fact that weak acids combine with wool at low *p*H to a far greater extent than hydrochloric acid is closely related to the greater swelling and higher heat of reaction In concentrated hydrochloric acid at a *p*H of 0 6 the wool fibers swell about 3 per cent, in monochloroacetic acid at the same *p*H 18 per cent, and in 98 per cent formic acid approximately 50 per cent

Effect of Alkalies on Wool

One of the most characteristic chemical properties of wool is the ease with which it is degraded in alkaline solutions A 5 per cent solution of caustic soda at boiling temperature completely dissolves wool in a few minutes. Investigations by Harris and Crowder and Speakman have shown that such degradation is closely associated with the tendency toward alkalies of the disulfide groups in the cystine of the wool It was found that, although the atomic ratio of nitrogen to sulfur in wool is about 10 to 1, these elements are removed from wool in the ratio of about 1 to 1 by the action of an alkali during the first stages of its attack If wool protein were

simply being dissolved, there should be 10 atoms of nitrogen in the solution for every atom of sulfur but the analysis showed that the sulfur was present in a much greater proportion About 40 per cent of the sulfur content of the wool is lost during an alkaline treatment which dissolves only about 9 per cent of the wool, but thereafter the sulfur is removed in proportion to the wool dissolved For example, treatment of wool yarn with a solution of caustic soda which is one-fourth normal (1 per cent by weight) reduces the sulfur content of the wool from its original value of 3.16 per cent to 1.85 per cent in twenty minutes at 50° C. The same result is obtained in four hours by the use of 0 065 caustic soda at 65° C. Further research by Harris brought forth similar results. (See Table 19.)

TABLE 19

CONTINUED ACTION OF 0 05 *N* SODIUM HYDROXIDE AT 65° C ON WOOL

Time of Treatment	*Loss in Weight Per cent*	*Alkali-Treated Wool*	
		Sulfur Content Per cent	*Cystine Content, by Sullivan Method Per cent*
Minutes:			
0	0 00	3 72	13 40
15	2.27	2 91	6 91
30	3 52	2 56	4 85
45	4 67	2 35	5 13
Hours:			
2	6 40	2.24	4.41
4	9.38	2 13	3 70
8	15.21	2 03	2 64
46*	61 50	2.28	2.65

*The samples became gelatinous and part of the residual wool was lost during washing The accuracy of these values is questionable.

The study of the course of the alkali degradation reveals that during the early stages a rapid splitting off of a portion of the sulfur occurs, closely approaching 50 per cent of the original amount of sulfur For each sulfur atom lost a molecule of cystine is destroyed and, according to Horn, Jones, and Ringe, a more stable sulfur, containing amino acid and having the formula (HOOC—(CH(NH_2)—CH_2)$_2$S, is formed. Mizell and Harris have found more than 25 per cent of the residual noncystine of sulfur left in alkali-treated wool as lanthionine. No significant amounts of sulfhydryl groups are in the treated wools. The mechanism of this

reaction as advanced by Nicolet and Shinn involves a rupture between sulfur and carbon to yield dehydroalamine and a —CH_2—S—SH residue An atom of sulfur is then eliminated from the latter and the sulfhydryl group thus formed reacts with dehydroalamine to form lanthionine

The injurious effect of alkaline solutions is of wide practical importance in view of the numerous alkali treatments which wool undergoes in being converted from raw stock to the finished fabric, in addition to the alkaline laundering which wool fabrics may receive in use Hence, soaps and scouring and fulling agents in general should be free from appreciable amounts of caustic alkalies. The weaker alkaline salts, such as the carbonates and soaps, are not so destructive in their action, and when employed at moderate temperatures they are not regarded as deleterious and are largely used in scouring and fulling

Barmore, in studying the effect of temperature of wool and *p*H of the scouring bath, found that for scouring raw wool, a temperature of 50° C is best; the *p*H value of the solution may range from 9 5 to 11 0, and the scouring time should not exceed ten minutes Under such conditions no damage occurs in the wool Barmore's findings check with practical experience in large-scale scouring

Data obtained by Harris show that breaking strength tests do not indicate alkali damage, since the strength of wool yarn may actually increase as the result of alkali treatment, due to the matting of the fibers, although the yarn may be harsh and practically dissolved Reflectance and compression resilience tests give more consistent measurements, but they fail to detect damage until it has become too apparent and serious

The action of concentrated solutions of caustic alkalies on wool is a rather peculiar one Studies of Speakman and of Barr and Edgar show that wool fibers are disintegrated by dilute NaOH solutions, the rapidity increasing with increased concentration of NaOH up to 15 per cent, beyond this point the strength of the yarn increases until 38 per cent of NaOH in solution is used Investigation of the action of caustic solutions on individual wool fibers under carefully controlled conditions showed that (a) the elastic properties of single wool fibers are completely unaffected after immersion in 38 per cent NaOH solution for five minutes at 19° C, (b) the immunity of the fibers is due to the low partial pressure of H_2O vapor in equilibrium with 38 per cent NaOH solution and to the formation of the complex hydrate $2NaOH \cdot 7H_2O$ with correspondingly low OH-ion concentration; (c) the 30 per cent

increase in the strength of wool yarn after immersion in 38 per cent NaOH solution is due to the surface gelatinization of the fibers which binds them firmly together in the dried yarn.

Soda ash, potash, and ammonia are not as destructive to wool, but their use must be kept below certain concentrations, depending on the temperature and time of the treatment; otherwise they have a yellowing and tendering effect. For example, soda solution used in raw wool scouring should be limited to 3 grams per liter or approximately 0.5 ounce per gallon at 130° F. and a pH of 11 with a total treatment time of ten minutes In piece scouring, when working at a temperature of 70° F. (20° C.) the concentration may reach 3 per cent or approximately 4 ounces per gallon at the start of the process. Ammonia is a weak base so, if used in concentrated solution, it causes disintegration even at low temperatures, but it may be used safely in a weak solution of 1 gram per liter for stripping purposes Wiegerink reports that wool treated with 0.1 per cent of carbonate solutions retains from 0.5 to 1 per cent more moisture than similar untreated wool.

The alkalies having the least effect on wool, perhaps, are ammonium carbonate and borax. Sodium phosphate is also a mild alkali which may be used in connection with wool without fear of injury. Whenever woolen goods are treated with alkaline solutions of whatever character, great care should be taken subsequently to give the material a most thorough rinsing in order to remove the last trace of alkali, as otherwise after drying and storing alkali spots may form, resulting in a weakening of the fiber and a discoloration of the goods. Also, if subsequently dyed, the pieces may exhibit streaks or spots due to the action of alkaline residues. Treatments of wool with oxidizing agents prior to an alkali treatment will increase the damaging effect of the latter.

Effect of Salts on Wool

Neutral metallic salts are not very reactive, as wool does not absorb them appreciably from their solutions. Neutral salts, such as common salts, Glauber's salt, potassium chloride, and magnesium sulfate, are hardly absorbed even in boiling solutions Lime and magnesium salts, present in hard water, may cause a yellowing effect on prolonged boiling or in "crabbing" and "blowing." Glauber's salt or sodium sulfate when used as a stripping agent for acid colors will give wool a harsh feel, as it has a dissolving action on the fiber substance in concentrations of 5 per cent or more In the presence of acids this harshening effect is far less pronounced

Certain salts are used with wool for the purpose of giving increased weight to the fabric Magnesium chloride is the loading agent most used because of its great hygroscopic properties. Magnesium sulfate and zinc chloride are used in a similar manner. According to Siefer, when wool is treated with concentrated calcium or barium thiocyanate solutions and then steamed, a considerable fiber contraction takes place. This reaction may be used to produce crepe effects in fabrics Similar effects result from the use of concentrated solutions of zinc chloride or sulfate, calcium chloride, or stannous chloride

With salts of heavy metals, in particular those of aluminum, iron, chromium, copper, and tin, wool is very reactive, the salts include the sulfates, chlorides, nitrates, and acetates When wool is boiled in solutions of these salts they combine with the wool to form water-insoluble compounds This is the reason why metal stains, such as iron and copper, are so common in wool processing

With salts which are acid in reaction and are capable of being easily dissociated in the presence of acids, such as alum, potassium bichromate, and sodium bichromate, the wool fiber possesses considerable attraction when boiled in their solutions The mordanting of wool with various metallic salts is based on this reaction as a previous preparation or an aftertreatment in dyeing of mordant colors such as with chrome dyes The metallic salt chiefly employed for the developing of mordant colors is sodium bichromate If wool is boiled in a 0 2 per cent solution of sodium bichromate, the wool takes up a considerable portion of the chromium compound, which imparts a yellow color to the wool The primary action is the absorption of chromic acid from the solution, to form a compound in which the wool substance acts as a base, combining with about 10 per cent of chromic acid The compound formed is stable in water In the presence of acids and certain organic compounds such as tartar, the action of the chrome compound is promoted and accelerated

Action of Oxidizing Agents on Wool

Wool is quite sensitive to oxidizing agents. Strong solutions of hydrogen peroxide, potassium permanganate, and potassium bichromate damage wool more or less, depending on the temperature, the concentration, and the *p*H According to Harris and Smith, the oxidizing agents attack the disulfide groups of the cystine, resulting in a lower strength, weight loss, increase in solubility in alkaline solutions, and reduction of the wool sulfur content

Stoves found that hydrolysis of the cystine linkage and subsequent oxidation give rise to sulfonic acids. The main use of oxidizing agents is in bleaching.

The most common oxidizing agent for bleaching wool is hydrogen peroxide, which gives the best permanent white. In strong solutions the wool is easily damaged by overbleaching or oxidation Smith and Harris found that the extent to which wool is oxidized depends on the concentration, temperature and *p*H of the hydrogen peroxide solution and the duration of the treatment. The data obtained by them clearly indicated critical values for the concentration, temperature and *p*H of the hydrogen peroxide solutions, but not for the duration of the treatment For example, by using a two-volume hydrogen peroxide solution the critical temperature is 50° C for a three-hour treatment The critical concentration is four-volume peroxide at a temperature of 50° C. When wool was treated with two-volume hydrogen peroxide solutions differing in *p*H for three hours at 50° C, it was found that the *p*H had no appreciable effect below a *p*H of 7. Between *p*H 7 and 10 the damage steadily increased. Above *p*H 10 the alkali concentration is sufficiently high to dissolve portions of the oxidized wool. In the presence of small amounts of metal such as copper and iron the damage through overoxidation may be greatly increased.

Dilute solutions of potassium permanganate may also be employed for the bleaching of wool When steeped in such solutions the wool acquires a dark brown color by reason of the precipitation of a hydrate of manganese in the fiber. Subsequent treatment with a solution of sodium bisulfate is necessary to remove the manganese compound, leaving the wool white Barr and Edgar made a special study on the degradation of wool by potassium permanganate

Spontaneous combustion of wool is the result primarily of processes of auto-oxidation In the presence of air and light the water content exercises a catalytic action on the fat or oil of the wool and the fatty acids which are produced promote oxidation, according to Lucchini

Action of Reducing Agents on Wool

Reducing agents attack, as do oxidizing agents the keratin molecule at its weakest link, the disulfide groups, forming sulfhydryl groups The splitting of the disulfide groups (according to Speakman) is corrected with the removal of the internal stresses present in the wool fiber The maximum *p*H values to produce these effects are at *p*H 4 and *p*H 10 A *p*H 4 concentrated solution

of bisulfites and metabisulfites destroys the disulfide group because of the swelling effect characteristic of weak acids and at pH values of 10 and higher the reducing agents act because the alkali hydrolizes the disulfide groups, forming sulfhydryl and sulfur acid groups The sulfur acid groups are then reduced through the reducing agent to sulfhydryl groups. Some alkali salts with reducing anions (Na_2S, and sodium thioglycolate) dissolve wool even in weak alkaline solution and at low temperatures, as found by Goddard and Michaelis.

Modified Wool

According to Speakman, when reduced wool is treated in solution with divalent metal ions (Ca, Ba, Zn, Cu, Ni) it is brought into a more stable form by the formation of new cross-linkages between the sulfur atoms of the type S—X—S (X = divalent metal) Speakman's work was the first step which confirmed the prediction that if wool's weak cross-links, the disulfide or cystine bonds, could be broken down and built up again in chemically stable form, the defects of wool would be eliminated or largely reduced and its desirable properties retained The metal-treated reduced wool has a higher stability toward steam and alkali

Harris and his collaborators went a step further toward this goal of chemically modified wool by breaking down the disulfide linkages with soluble organic sulfur compounds, known as mercaptans, and reconstituting the reduced wool with alkyl dihalides The best results were obtained by using thioglycolic acid (0 2 M) at a pH of 4 5 as a reducing agent and subsequent alkylation of the reduced product with trimethylene dibromide The reaction with the dihalides results in the formation of new cross-links in which sulfur atoms of the cystine are connected by short hydrocarbon chains The reaction appears to affect only the disulfide groups of the cystine in wool and may be represented by the following equations

$$\underset{\text{Wool}}{W—S—S—W} + \underset{\text{Thioglycolic acid}}{2HS—CH_2—COOH} = \underset{\text{Reduced wool}}{2W—SH} + \underset{\text{Dithioglycolic acid}}{(S—CH_2—COOH)_2} \quad (1)$$

$$\underset{\text{Reduced wool}}{2W—SH} + \underset{\text{Trimethylene dibromide}}{(CH_2)_3Br_2} = \underset{\text{Modified wool}}{W—S—(CH_2)_3—S—W} + \underset{\text{Hydrobromic acid}}{2HBr} \quad (2)$$

The analysis showed that the modified wool contained 6 5 per cent cystine, the mode linkage of approximately half of the sulfur atoms had been altered, since untreated wool contained 12 4 per cent cystine

The change in the physical and chemical properties of modified wool yarn produced on a laboratory scale is given in Table 20.

TABLE 20

PROPERTIES OF MODIFIED WOOL IN YARN FORM

Type of Wool	*30 Per cent Index*	*Breaking Strength of Yarns (grams)*	*Alkali Solubility (per cent)*	*Moisture Content (per cent)*
Untreated	0 99	1310	10 5	16.0
Reduced	0 65	1170	50 0	....
Modified	0 90	1460	5 3	16.0

In addition, tests have shown that modified wool seems to be not only more resistant to alkalies but also to attack by moths, enzymes, and bacteria It is more resistant to shrinking in laundering, with a "feel" only slightly harsher than that of untreated wool. Its affinity toward acid and chrome dyes is increased

Action of Halogens on Wool

Treatment of wool with chlorine, bromine, or iodine leads to adsorption and chemical change The size and type of the chemical change depends essentially on the presence of water Depending on the conditions of the chlorine solution, the wool fiber undergoes rather remarkable transformations, leading to a considerable alteration in its physical and chemical properties It may become harsh and yellow, acquire a high luster, lose its felting ability and, at the same time, show an increased rate of dyeing These three properties of chlorinated wool lead to the commercial application of halogenation for the purpose of lustering of oriental rugs, in the manufacturing of nonfelting yarn for socks, underwear, and sweaters, and in the printing of woolen fabrics to increase their dye affinity

According to Vom Hove, in the reaction of dry Cl, Br, and I in the gaseous state or in nonaqueous inert solvents, upon completely dry wool only a slight chemical reaction takes place with the wool protein (substitution) Halogens with normal moisture content are adsorbed by dry wool, with haloamine formation Furthermore, some substitution and a small amount of oxidation of wool protein take place In aqueous solution a very rapid consumption of Cl and Br by the wool takes place, where the halogens go through the hypoacid and haloamine stage and effect a hydrolytic splitting of the wool

protein by oxidation and haloamine decomposition, with formation of the corresponding halo-H acids The resulting peptones, polypeptides, and reactive amino groups immediately enter into a chloramine or bromamine formation From the haloamines, HCl and HBr are formed, which effect new hydrolytic splitting At the same time active halogen penetrates to the interior of the fiber, where it forms halogen-H [illegible] with water, which oxidizes the fiber. A substitution of the halogens in the tyrosine of the wool protein takes place also The resulting halogen-H acids give rise to a Donnan membrane equilibrium and the blistering of the fiber surface known as [illegible] The blisters or swellings rise on the surface of the [illegible] Hock, Ramsay, and Harris have shown that these [illegible] arise from the scales and their formation is associated [illegible] of the chlorine with disulfide groups of the cyst[illegible] where the cystine content is low because of degradation by [illegible] alkali the sacs do not form.

With iodine the [illegible] fiber surface is considerably slower than with other halogens, with the result that iodine penetrates almost excl[illegible] by ad[illegible] from the solution to the interior of the fiber, wh[illegible] slowly [illegible] The amounts of halogen substituted in the [illegible] of the protein increase with rising initial concentration of the halogen solutions in the ratio of simple multiple proportion to a maximum value which is six times that of the smallest [illegible] halogen [illegible] The increased dyeing capacity of halogen[illegible] wool is the result of the destruction of the outer fiber layer, which exposes the interior of the fiber to the dyes. The destruction of wool effected by the oxidizing action of the halogens increases with rising halogen concentration.

Nonfelting Wool

Processes for reducing the felting properties of wool became very important during World War II because of the necessity of buying woolen underwear and socks for the armed forces which would not shrink when washed It is essential to remember that there are two types of shrinkage in woolen fabrics, namely, the relaxation shrinkage which occurs in steaming pressing, and sponging, and the shrinkage due to felting in washing The relaxation shrinkage arises from the relaxation of the fibers which were stretched when they were processed into yarn and fabrics Yarns and fabrics are held taut during spinning and weaving and fabrics

are stretched in both length and width during the final stages of finishing This stretch has to be removed by shrinking the fabric before making it up into garments In the process known as London shrinking stretched, wet wool fabrics are allowed to relax and are dried after all the stretched fibers have had an opportunity to return to their normal lengths

Fabrics made from nonfelting wool tend to show the same amount of relaxation shrinkage as similar fabrics made from normal wool On the other hand, while normal garment fabrics will rapidly contract in size in washing with warm soap solutions because of the felting action, garments made of nonfelting wool will retain more or less their original size

Elasticity and the frictional effect of scale surface are responsible for shrinkage due to felting of the wool fiber. Therefore, either the elasticity of the wool fiber or the directional frictional effect of its surface must be destroyed to prevent its felting Since the elasticity of the fiber is the most valuable property, all methods of reducing the felting properties of wool aim at destroying or altering the frictional properties of the fiber surface It is known that any chemical reagent which attacks and rounds off the free edges of the epidermis scales diminishes the felting properties of woolen fabrics With the newest methods the scale structure is preserved but, according to Speakman and Goodings, the layer under the scales is converted into a degraded protein capable of swelling under the action of acids and alkalies Because the scales rest on this insecure foundation they no longer exert a directional effect on the frictional properties

Of all the chemical reagents which attack the scales of wool, chlorine is the most powerful and, therefore, it was first used to produce a non-shrinkable finish on hosiery, undergarments, shirts, trousers, and vests which are frequently washed The process most widely adopted was wet chlorination, which consists of treating the fabric or fashioned garments with acidified solutions of either sodium hypochlorite or bleaching powder This process is difficult to control because chlorine has a great affinity for wet wool and skill is needed to see that every part of a large batch of fabric or garments absorbs the same amount of chlorine The many new processes which have been developed since 1925 are summarized in the table of patents, Table 21.

Chlorine water, chlorine gas, the organic hypochlorites, sulfuryl chloride, and nitrosyl chloride all act by causing oxidation of the disulfide sulfur, thereby disorganizing the surface layers of the wool.

Probably the bisulfite used in the enzyme method also reacts on this disulfide sulfur, but in addition the enzyme brings about the breakdown of the polypeptide chains Instead of producing disorganization by oxidation, the methods involving the use of alkalies produce disorganization by hydrolysis and disruption of the disulfide linkage and, also, possibly of the polypeptide chains

The application of synthetic resins is a new trend The modification that the fibers undergo by the incorporation of the water-soluble

TABLE 21

CHRONOLOGICAL LIST OF PATENTS ON NONFELTING WOOL

Inventors	*Chemicals Used*	*Year Issued*	*Patent Number*
Trotman	Hypochlorous acid	1925	U S 1,522,555
Jackson, E L	Tertiary-butyl hypochlorite and methyl alcohol in an inert solvent	1929	U. S 2,132,342
Reichart, J S, and Peaker, R. W	Tertiary-butyl hypochlorite in an inert solvent	1930	U S 2,132,345
Smith and Ruby	Sodium hypochlorite and alkali	1930	U S 1,781,415
Feibelmann, R	p-Toluene sulfondichloramide and HCl,	1932	U S 1,892,548
King and Galley (Wool, T R. Assoc)	Dry chlorine or bromine gas at low pressures	1933	E 417,719
Irvinebank Dyeworks	"N S " process—wet contact process	1935	
Hall, A T	Sulfuryl chloride in an inert solvent	1935	U S 2,107,703
Phillips and Middlebrook	Papain in a sodium bisulfite solution	1938	E 513,919
Wiegand	Sodium hypochlorite + H_2SO_4 + amines	1938	U S 2,144,824
Solvay Process Co	Nitrosyl chloride	1939	U S 2,213,399
Freney and Lipson	Caustic soda and potash in methylated spirits	1939	
Hall, Wood and Tootal Broadhurst Lee Co, Ltd	Inorganic and organic bases in mixtures of alcohols and inert solvents	1939	E 538,396 E 538,428
Parker, Farrington Stubbs, Speakman, and Bleachers' Assoc, Ltd	Inorganic sulfides in mixtures of alcohols	1940	E 539,057
Clayton and Edwards	"Negafel"—chlorine in aqueous solutions containing formic acid	1940	E 537,671
American Cyanamid Co	Alkylated methylol-melamine	1943	U S 2,329,622
Raynes, J L and Stevenson, F M	Hypochlorite and permanganate	1945	E 569,730

methylol melamine type resin appears to be of a purely physical nature With the fibers thoroughly penetrated the formation of the resin in the process of polymerization will take place within the cortical cells as well as on the surface of the epidermis cells The outside film probably reduces the frictional forces of the scales, whereas the resin within the fiber affects its elastic properties

From the number of patents granted it is obvious that a great deal of experimental work has been done and that the methods now available to produce nonshrinkable wool are bewildering in their variety Some of these processes are, of course, in a more advanced state of development than others In England, according to Phillips, the dry chlorination process, the "N S" process, the sulfuryl chloride

process, and the Negafel process have already set a new standard of unshrinkability and, with improved wet processes, led to big economies in the wool required by the British armed forces. In the United States the development was retarded by unfortunate experiences with some processes and the disinterested reaction of the general public

Early in 1944 the United States Army began to include in its specifications a nonfelting treatment for cushion sole socks, and developed a simplified modification of a wet chlorination process By the end of 1944, the Army was purchasing 7 million pairs of fully washable cushion sole socks per month, whereas in 1943 it had been buying none. Shrinkage of untreated socks amounted to 22 per cent after only twelve days' average wear After treatment, shrinkage was reduced to only 5 per cent after forty-six days' average wear The effected savings were estimated at $1,500,000 per month on shrink-resistant socks alone.

By the end of the war in 1945, the United States Quartermaster Corps extended its research in this field to include the application of

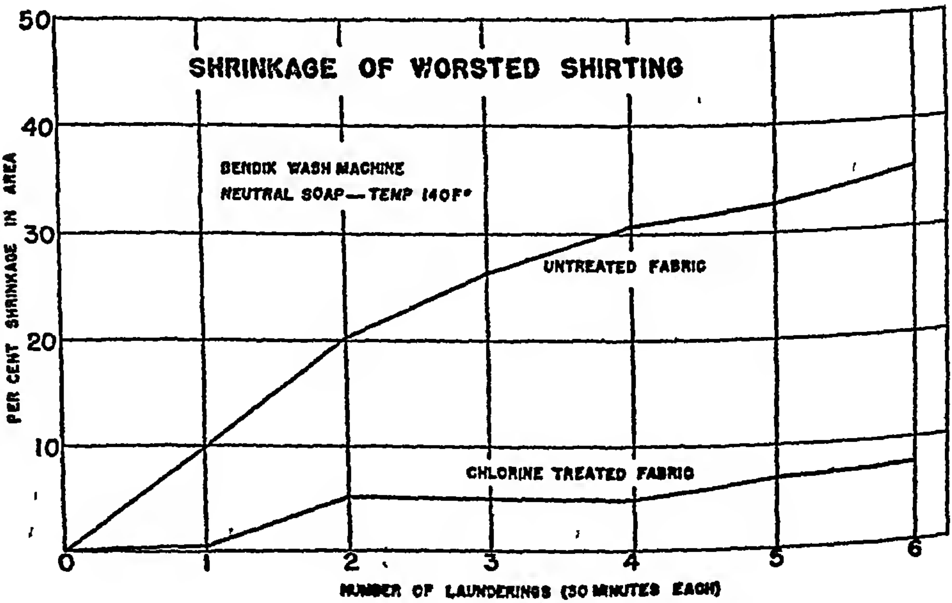


Fig 8. Retardation by dry chlorination of felting of worsted shirting

wet chlorination and several other processes including resin treatments to flannel shirting, blankets and woolen underwear with the aim of supplying troops in the future with washable woolen equipment Figures 8 and 9 show in graphical form the extent to which felting of fabric can be retarded by dry chlorination and by the melamine resin process.

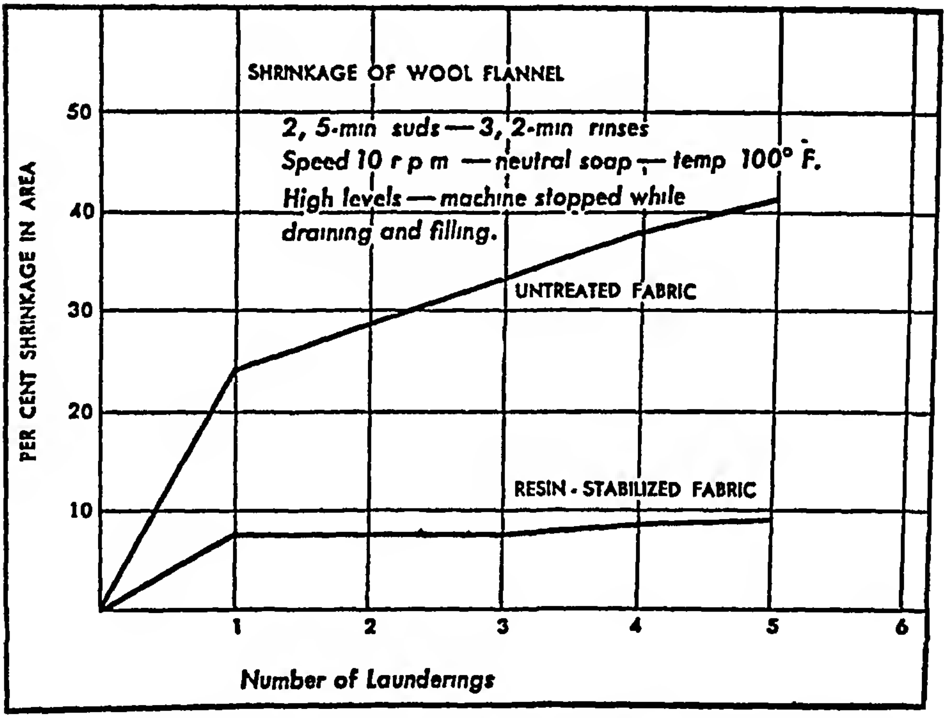


Fig 9 Retardation by melamine resin of shrinkage of wool flannel

Action of Formaldehyde on Wool

Formaldehyde may be used for two purposes (1) as a protective agent against the chemical action of alkalies, and (2) for sterilization The protective action is also effective against the damaging influence of steam and of boiling water Barr and Edgar reported a protective action even against acid Wool treated with 4 per cent solution of formaldehyde shows, in addition to the resistance toward alkalies, a decreased dye affinity and also a loss of its felting properties

Speakman and Peill found that the increased resistance of formaldehyde-treated wool fibers is a result of the formation of resistant cross-linkages The treatment is best carried out at pH 6 to 7 There is a sharp decline in the extent of cross-linking, until damage is accentuated in solutions at pH 11.2 and above.

The sterilization value of formaldehyde has been studied by Humfield, Elmquist, and Kettering on a worsted serge Formaldehyde solutions were effective sterilizing agents when used either in a 2½ per cent or stronger concentration for one hour or in an 8 per cent concentration for thirty minutes When formalin vapors were used, it was necessary to expose the fabric for two hours at 70° C. The formaldehyde treatments softened and bleached the fabrics For disinfection of blankets and clothing such treatments are useful

Quinone, which, like formaldehyde, is capable of forming cross-linkages between the peptide chains of animal fibers, was first used by Meunier to prevent damage According to Speakman and Peill, the maximum cross-linkage formation with quinone takes place at pH 4 7

Dye Affinity

Concerning coloring matters, wool is the most reactive of all textile fibers combining directly with most of the synthetic organic dyes The affinity changes with the different chemical compositions of the dyes and, consequently, the conditions also vary under which the union of the dyestuffs with the wool is best brought about The most important dyes for wool are the acid, chrome, and vat types

Mildew and Bacteria

From the time wool grows on the sheep on through the stages of manufacture and wear, the fibers are subject continually to contamination by microorganisms Included in this microorganic flora may be pathogenic organisms which are responsible for disease, and many other groups, many of these are capable of multiplying rapidly under favorable conditions and causing the wool fibers to be stained with mildew or to lose strength and to deteriorate in other ways

Wool is the fiber least attacked by mildew and bacteria In shipping tightly packed raw wool it happens occasionally that such bales get wet, either through rain or by dropping into the water when being loaded or unloaded from a steamer The wool will soon de-

velop a fungoid growth or mildew in spots. In manufacturing woolen goods, if sized material which is loaded with starch or glue becomes wet, fungoid growth is likely to occur. Usually no damage is done through mildew alone

A study on the microbiology of raw wool was made by Prindle, who reported the change in the number of bacteria and molds in one lot of wool as shown in Table 22.

TABLE 22

NUMBER OF BACTERIA AND MOLDS PER GRAM IN WOOL

	Raw Wool	*Shaken Wool*	*Scoured Wool, Wet*	*Scoured Wool, Dried*
Molds	2,700	36,000	300	300
Bacteria, all types	1,200,000	17,000,000	65,000,000	3,400,000
Bacteria spores	190,000	210,000	100,000	110,000

The increase in number of molds may be the result of shaking, which, instead of removing most of the mold spores from the wool by eliminating much of the earthy and vegetable matter, tends rather to distribute such material more evenly throughout the fiber mass and so stimulates a higher degree of contamination In the scouring bowls, the larger part of the original mold flora was either washed off or killed in the scouring bath The number of bacterial colonies increased tremendously through shaking and scouring, because of the constant mixing of the fibers from all parts of the lot Through the drying process the total number of bacteria of all types dropped from 65,000,000 to 3,400,000 This suggests that the heating of the fiber for drying acted as pasteurization and inactivated the less heat-resistant vegetative forms

If wool is stored in a warm place in a moist alkaline condition, with no circulation of fresh air, bacteria start to grow and produce enzymes, which rapidly break down the fiber scales and hydrolize the intercellular substance that holds together the individual cells of the corticular layer until they split open and fall apart Research by Geiger, Patterson, Mizell, and Harris on the nature of the resistance of wool to digestion by enzymes gave the following result:

> Wool that has neither been injured mechanically nor modified chemically is completely resistant to attack by the proteolytic enzymes—pepsin, trypsin, chymotrypsin, and papain When the cuticle or scale layer of the fibers is damaged by mechanical means, the wool becomes susceptible to attack by pepsin and chymotrypsin Under these conditions only a small portion of the

wool is digested, yet the fibers are considerably weakened and their fibrous structure is partly destroyed

Wool in which the disulfide cross-linkages have been broken, as by reduction, or by reduction followed by methylation, is almost completely digested by pepsin and chymotrypsin, but is attacked only slightly by trypsin. When the reduced wool is re-oxidized and its sulfhydryl groups are converted to disulfide groups, the wool regains its original stability. When the sulfhydryl groups of the reduced wool are converted to bis-thio ether groups by the action of an aliphatic dihalide, the stability of the wool toward enzymes is greatly enhanced

Spore-forming bacilli, particularly those which liquefy gelatin, cause the most damage to wool, according to Trotman and Sutton. Cocci are less harmful than bacilli Different organisms produce damage at different rates, each growing best within certain limits of *p*H Through this bacterial action a large amount of heat is produced A temperature of 40° C (104° F) was measured inside bacteria-attacked bales

Burgess says that mildew on cellared or aged and stored goods is due to mold fungi rather than bacteria Soaps, wool creams, and the majority of conditioning fluids encourage mold development because of the alkali present, which, by combining with the wool, renders it more easily attacked In hygroscopic soaps mold growth can occur over a wide range of humidity Vegetable oils such as olive oil increase mildew growth, but to a smaller extent than soap, in this connection the nutritive value of the oil is important Lower fatty acids, such as hexoic, octoic, and lauric acids, retard mold growth, on the other hand, the more complex fatty acid, oleic acid, favors growth Mineral oils have a protective effect and are not used as food by the mold fungi Greenish-yellow stains commonly found on mildewed wool are caused by mold action on the soap present The reaction range over which mold growth can occur on wool is considerable, since both acid and alkaline conditions favor it

The preponderant factor in the development of mildew is the presence or absence on the wool of degradation products of the fiber proteins All treatments which remove these products remove the possibility of development of molds; such treatments are equally effective whether carried out before, during, or after dyeing The most important and simplest of these treatments is chroming; the efficiency of the chrome dyes is the result, not of their constitution but of the fact that treatment with chromium removes the protein degradation products which are always present on the wool This confirms the findings of Burgess.

Protection is obtained also by aftertreatment of certain direct dyes

with copper sulfate, chromium fluoride, or formaldehyde, but in these cases the action is the result of the bactericidal power of the chemicals rather than of the removal of the degradation products of the proteins, so that the protective action is much weaker than with chroming. Where the bacteria damage occurs before dyeing the damage will appear as light spots after dyeing In indigo-dyed goods reduction of the dye takes place, resulting in its destruction

Moth Larva and Carpet Beetle Damage

Woolen and worsted fabrics are readily eaten by larvae of clothes moths and carpet beetles There are two distinct types of moth larvae which cause an estimated annual loss of some $100,000,000 to consumers alone for damages and expenditures for their control. The two differ mostly in the type of cocoon in which they pass their dormant stage and have been named accordingly, i e, webbing moth (*Tineola bisellicella Hummel*) and case-bearing moth (*Tinea pellionella*)

The carpet beetle larvae, from which come "buffalo moths," are known as "dermestid pests," because they belong to the Dermestidae family There are four of these, the common carpet beetle (*Anthrenus scrophulariae*), the furniture carpet beetle (*A vorax*), the varied carpet beetle (*A verbasci*), and the black carpet beetle (*Attagenus piceus*).

The damage caused by insects, especially by the moth larva (*Tineola bisellhella hummel*) is easily recognized microscopically The attacked fibers show the biting marks produced by the cutting and chewing tools of the larva The head of the larva (Fig 10) shows the remarkable biological and mechanical structure of the organs which serve the insect well as cutting and chewing tools for textile fibers and even harder materials, such as horn, quills, etc The organs of the lower jaw are. the underlip (mentum and submentum), two maxillae projecting like telescopes to the left and right of the underlip, and the true biting jaws, the mandibles, in front of the maxillae

The mandibles, when not in motion, are somewhat comparable to a pair of mole's feet They are of chitin and are red-brown in color. They are triangular and hollow and are fastened to the lower edge of the cranium by ball-and-socket hinges On its upper part (dorsal), each mandible is provided with five cutting teeth arranged similarly to the fingers on the palm Nature's building method is interesting, using the principle of angle beams to build this important organ of the larva's head as light as possible. The

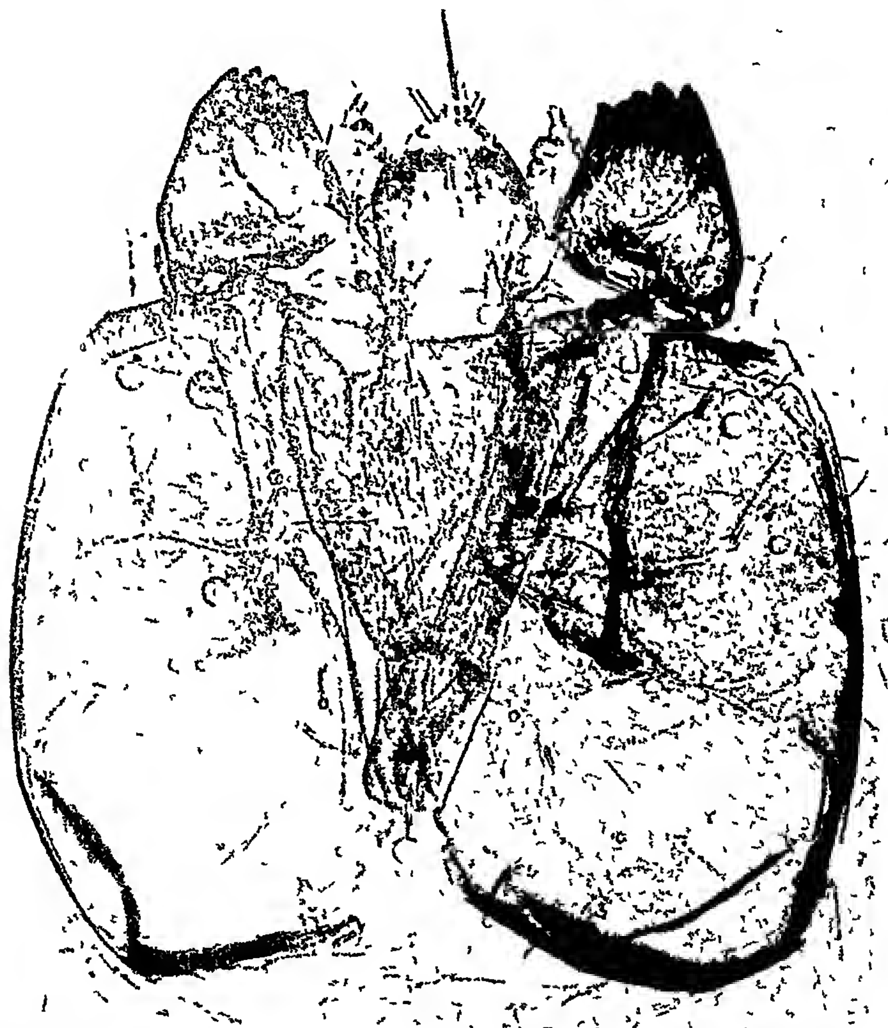


FIG 10 Head of moth larva detached from body Facial view Left and right from the wedge-shaped middle part, the lateral hemispheres In front of these (above, in photograph) the dark brown mandibles, next to these, right and left, the antennae Visible between the mandibles, in reality under these, the underlip organ, the submentum with the labium, the spinneret and the maxillae.
Courtesy Textile Research Institute, Inc Moth Report, Reumuth

two converging chitin walls are reinforced on the inside by angle beams.

A part or a whole image of the profile of the mandibles with the five chitin teeth is frequently seen on the attacked fiber. Some fibers are attacked from the side, almost at a right angle to the axis of the fiber. If the cut is superficial, from the side, pictures can be obtained like that of *A* in Figure 11, which shows a number of wool fibers. If the cut is deeper, a rupture occurred on the narrowest point in most cases, as in *B* and *C*.

Similar forms of cuts can be found after attacks of dermestids (larvae of carpet beetles). It is impossible, however, from such eaten fibers to determine the exact kind of insect A complete biological investigation is necessary to determine whether tineids or dermestids were at work

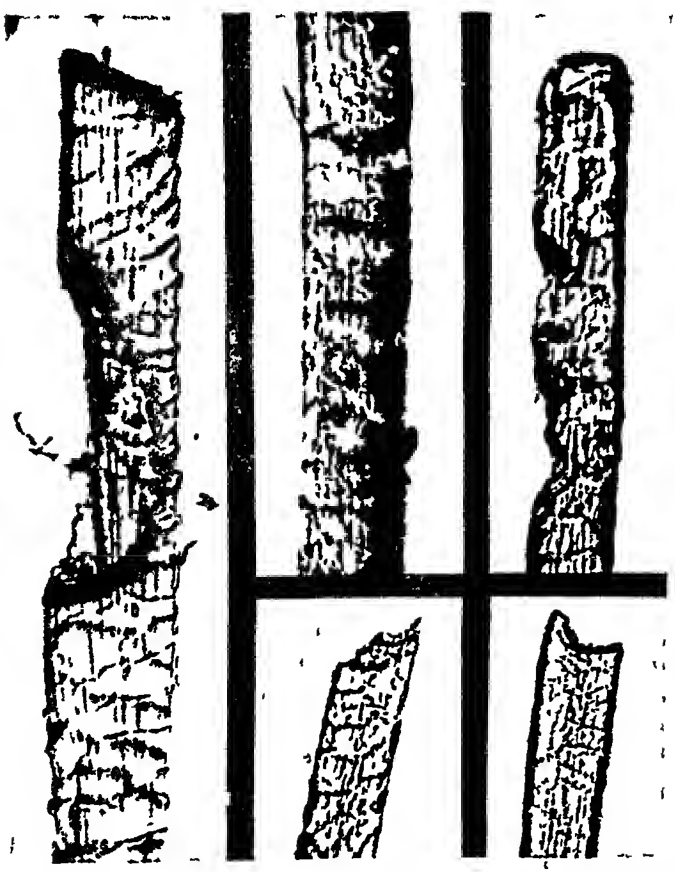


Fig 11 Biting forms of larva on animal fibers *Reumuth*

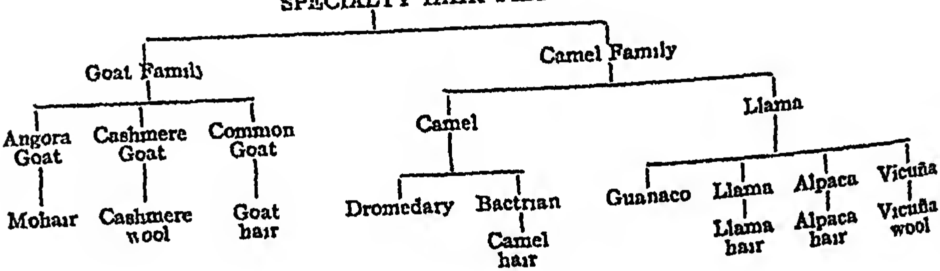
In recent years the mothproofing of woolen and worsteds has gained in importance because of the discovery of effective chemical compounds and simpler means of application (*See Chapter* 18, *Dyeing, Bleaching and Printing*).

Chapter 5

SPECIALTY HAIR FIBERS[1]

BESIDES the fiber obtained from the various types of sheep, large quantities of animal fibers not strictly classifiable as wool but known as specialty hair fibers are used in the manufacture of clothing. They are used in conjunction with wool to produce special effects or to give additional beauty, color, softness or luster. These fibers are obtained from related species of animals, such as goats, camels, cows, horses, and fur-bearing animals. The chart below indicates the various animals yielding these specialty fibers.

SPECIALTY HAIR FIBERS



Mohair

Mohair is the main specialty hair fiber and forms the long lustrous coat or covering of the Angora goat, which originated in Asia Minor The goat owes its name to the province of Angora in Turkey, where it has been cultivated for thousands of years Today three countries—Turkey, the Union of South Africa, and the United States—breed this goat on a commercial basis for the quality of its hair.

World production of mohair Table 1 shows that the United States today is the largest producer as well as the largest consumer of mohair. In the ten years previous to World War II, the United

[1]This chapter is largely taken from J Merritt Matthews and H R Mauersberger, *The Textile Fibers*, 5th Edition, by permission of the publishers, John Wiley & Sons, Inc, New York, 1947

States imported annually 350,000 pounds of mohair in addition to its own production and during World War II approximately 700,000 pounds Demand for mohair in the United States has increased to such an extent that in 1944 alone, the United States produced 20,000,000 pounds and its imports exceeded 6,000,000 pounds

TABLE 1
HEAD OF GOATS AND MOHAIR PRODUCTION IN PRINCIPAL COUNTRIES
[In millions]

Years	*United States*		*Union of South Africa*		*Turkey*		*Total*	
	Head	*Pounds*	*Head*	*Pounds*	*Head*	*Pounds*	*Head*	*Pounds*
1932	4 201	16 9	1 511	6 4	3 315	7 9	9 027	31 2
1933	4 092	16 5	1 339	15 7	3 081	7 0	8 512	39 2
1934	3 916	16 2	0 944	6 5	2 637	7 7	7 497	30 4
1935	3 565	15 7	0 742	10 6	2 743	12 1	7 050	38 4
1936	3 715	16 1	0 700	6 3	3 193	13 9	7 608	36 3
1937	3 774	16 5	0 700	4 6	3 700	12 0	8 174	33 1
1938	3 918	16 8	0 700	5 1	3 200	16 3	7 818	38 2
Averages	3 883	16 4	0 948	7 9	3 124	11 0	7 955	35 3
Per cent	48 9	46 5	11 8	22 4	39 3	31 1	100 0	100 0

Source National Association of Wool Manufacturers, *Bulletin*, Vol LXIX, 1939

Development of the mohair industry Up to the early part of the nineteenth century the breeding of mohair goats was limited to Turkey Many attempts were made to establish Angora goats in Europe, but these attempts were not successful The rapid growth of manufacturing in Europe in the first half of the nineteenth century created a demand for mohair far in excess of what the Turks were able to meet By 1860, efforts were directed to the production of mohair in South Africa by grading up the herds of common goats with imported sires The first importation of Angora goats into South Africa took place in 1838 Up to 1880, about 3000 Angora goats had been imported and the industry had become firmly established

U S mohair production It is now over three-quarters of a century since the first importation of Angora goats into the United States A short time after the annexation of Texas by the Union, during the administration of President Polk, the Sultan of Turkey requested him to recommend someone to experiment in the production of cotton in Turkey James B Davis, of Columbia, S C,

was recommended, and he received the appointment. When Doctor Davis returned to the United States in 1849, he brought with him nine choice goats, comprising seven does and two bucks. Ten years later just before the outbreak of the Civil War, there were many fair-sized herds of Angoras in the South and the Southwest. Smaller herds were also maintained in the North and the West. Soon after the close of the war the growing of Angora goats spread into the West, principally into Texas and California As the natural condi-

TABLE 2
U S MOHAIR PRODUCTION AND INCOME, 1944 AND 1945

	1944					1945*				
State	Goats clipped†	Av clip per goat	Production	Price per pound	Cash Income	Goats clipped†	Av clip per goat	Production	Price per pound	Cash Income
	Thous	Lb	Thous lb	Cents	Thous Dol	Thous	Lb	Thous Lb	Cents	Thous Dol
Missouri	78	2 6	203	46	93	75	2.7	202	40	81
Texas	3,570	5 1	18,200	61	11 102	3 855	5.3	20,360	56	11 402
New Mexico	175	4 9	855	57	487	132	5 1	675	52	351
Arizona	164	4.5	730	57	416	130	4.3	560	51	286
Utah	20	5 2	104	43	45	15	5 2	78	41	32
Oregon	90	3.8	342	44	150	85	3 6	306	42	129
California	23	3 6	83	42	35	22	3 6	79	38	30
Total	4 120	5 0	20,517	60 1	12,328	4,314	5 2	22,260	55.3	12 311

* Preliminary figures † In states where goats are clipped twice a year the number clipped is the sum of goats and kids clipped in the spring and of kids clipped in the fall.

TABLE 3
U S MOHAIR PRODUCTION IN POUNDS, 1900–1945

Year	Weight of Mohair (pounds)	Year	Weight of Mohair (pounds)
1945	22,260,000	1934	16,180,000
1944	20,517,000	1933	16,540,000
1943	20,196,000	1932	16,940,000
1942	20,730,000	1931	19,380,000
1941	21,780,000	1930	17,580,000
1940	21,140,000	1925	11,150,000
1939	18,790,000	1920	8,570,000
1938	16,830,000	1915	6,540,000
1937	16,530,000	1910	5,920,000
1936	16,120,000	1900	961,000
1935	15,720,000		

Source. U S. Department of Agriculture.

tions in those regions proved to be best suited to Angoras, the greatest development of the Angora goat industry has taken place in that part of the country, particularly in Texas and, to a considerable extent in New Mexico, Arizona, California, Oregon and, of late, Utah The greatest concentration of Angoras in this country is on the Edwards Plateau of western Texas

Mohair production in the seven leading states in 1945 was estimated at 22,260,000 pounds by the Department of Agriculture This quantity was 1,743,000 pounds, or 8 per cent, above the 20,517,000 pounds produced in 1944, and 21 per cent above the ten-year (1934-43) average.

The number of goats clipped in 1945, estimated at 4,314,000 head, was up 5 per cent from the 4,120,000 head clipped in 1944 and was the third largest on record The average quantity of hair per goat and kid clipped was 5 2 pounds in 1945 compared to 5 0 pounds in 1944 It was the highest clip per goat on record.

Estimated income from mohair in 1945 amounted to $12,311,000, just $17,000 under the 1944 income of $12,328,000 The average price per pound for mohair was 55 cents compared with 60 cents in 1944

Table 2 shows the estimates of production and of income from mohair by states for 1944 and 1945

Improvement of Angora goats Angora goats in the United States have been developed through a long period of selective breeding This has been accomplished by the use of imported stock and by crossing the improved Angora bucks on a foundation of common does.

Since 1900 a registry system has existed for Angora goats established by the American Angora Goat Breeders' Association, Rock Springs, Texas This system was initiated by means of official inspection of pure-bred and high-grade American Angoras and by admitting to the official register only such animals as measured up to the standard of excellence required by the association As a rule, range herds of goats are composed of select high-grade does that are mated with pure-bred bucks purchased from breeders who specialize in the production of superior registered animals

Characteristics of improved Angoras Mature bucks usually weigh about 130 to 135 pounds; 18-month-old bucks, 75 to 80 pounds, mature wethers, 90 to 140 pounds, mature does about 75 pounds and 18-month-old does around 65 pounds (Fig 1).

The production of unscoured mohair per goat is about 3½ to

4½ pounds for the doe and kid band under range conditions, and for wethers about 4 to 5 pounds. The average weight per fleece which in the period 1920-1924 was 3 8 pounds increased to 4 8 pounds in the period 1940-1944. Much of the mohair is taken off in two clips per year. This is particularly true of mohair grown in the Southwest Pure-bred herds often clip double the above quantities Both bucks and does have horns. The ears should be drooping The color of all Angoras is white "Red kids" are born occasionally.

Types of fleeces. There are three primary types of fleece based on the formation of the lock, viz . the tight lock, the flat lock, and the fluffy fleece Angora breeders generally prefer a well-developed tight lock or ringlet, although some prefer the flat lock, which produces a very desirable type of mohair. The tight lock is ringleted

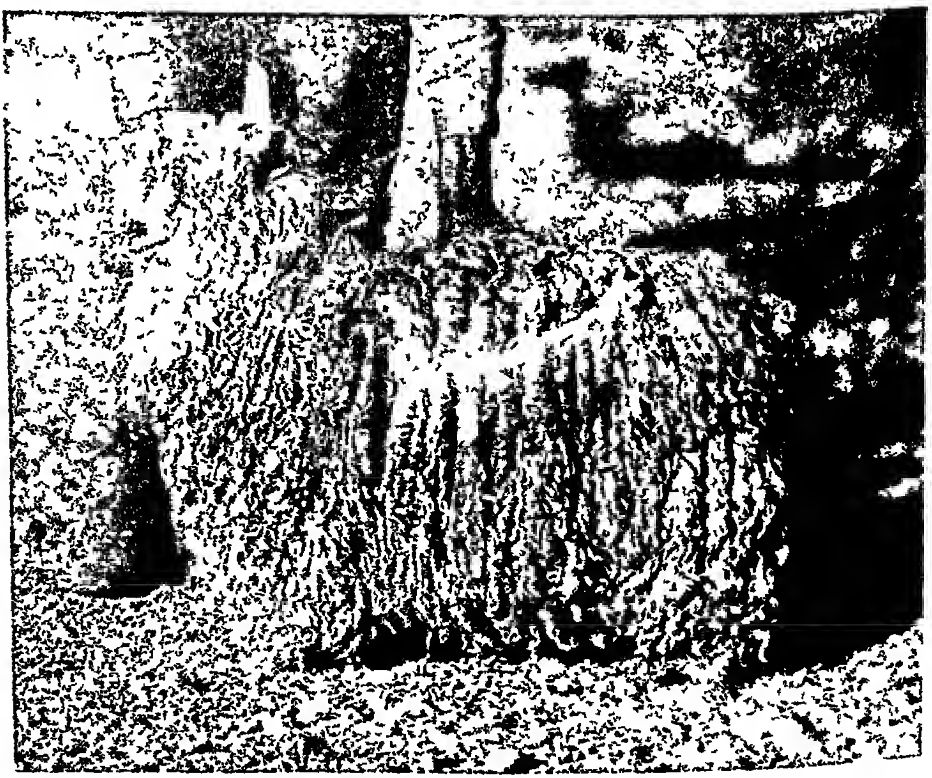


Fig 1. Texas mohair doe—Type C *Courtesy U S D A*

throughout almost its entire length It is the type that is most strongly associated with extreme fineness of mohair (See Fig 1) The flat lock is usually wavy and forms a bulky fleece This lock is usually associated with heavy shearing weight and a satisfactory quality of hair. The fluffy or open fleece probably stands lowest in character, and is objectionable on the range because it is easily broken and is torn out to a greater extent by the brush. One of the most important problems in the improvement of Angora goats and their mohair is the elimination of the kemp fibers, which greatly reduce the value of the fleece A great advance has been made in this direction since 1920.

Management of Angora goats A large portion of the Angora goats in the United States are maintained under range conditions Angora goats are especially adapted to the use of many kinds of range forage, and since they can be handled in large herds, they lend themselves to very economical use of certain range lands Browse furnishes most of the forage for goats on the ranges Dur-

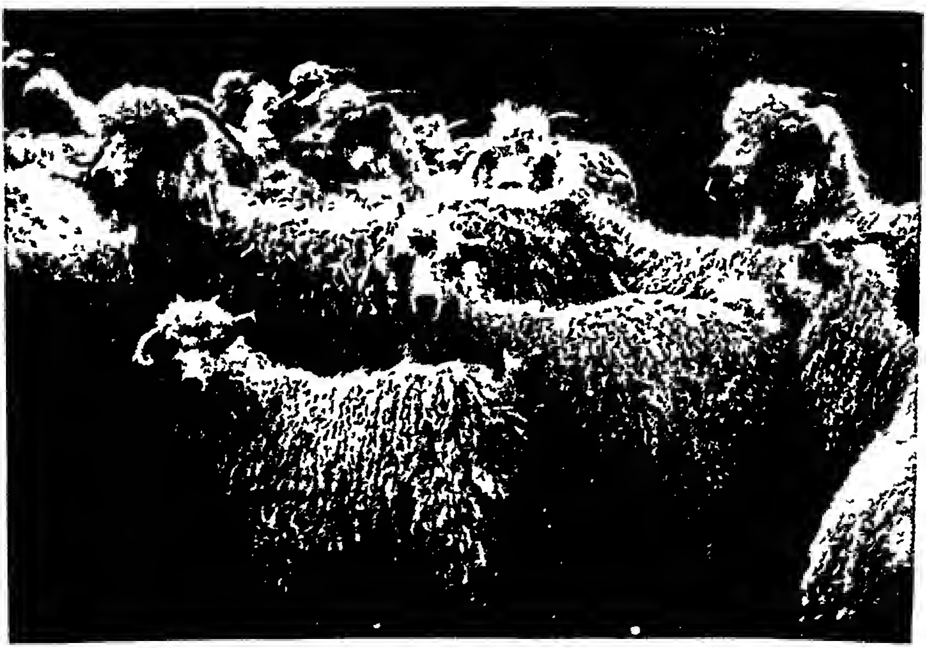


Fig 2 Angora goats with kids (Texas) *Photo by Pix*

Fig 3 Distribution of Angora goats in the United States, 1940

ing the summer, browse and grass are often grazed in approximately equal quantity, provided about equal amounts of palatable species of both make up the forage In the winter, however, browse is the principal goat feed, and is absolutely necessary on any winter goat range which is subject to continual snow.

Most goat ranches in the range country, especially in the Southwest, consist of the headquarters, kidding and shearing facilities, and sheds for winter protection On the range, goats are grazed in herds of a few hundred head to over 2000 General range practice has shown, however, that on timbered mountain ranges it is most economical to graze goats in herds of approximately 1200 head of mature animals

The time of year to breed the does varies for different parts of the country, but as March and April are the months in which most of the kidding occurs, the breeding season is chiefly in the months of October and November In the spring, goats are sheared as soon as the weather permits and when all danger of cold rains has passed In the Southwest, on account of the warmer climate, goats are shorn twice a year, spring and fall Goats are shorn with hand shears or with machine clippers Before the body of the goat is sheared, all tags,

dung locks, and stained pieces should be removed These sorts should be packed separately The fleeces from kids, those from the middle-aged goats, and those from old goats, which have straight and coarse mohair, should be packed separately It is quite a general practice to pack the kid mohair by itself The cost of shearing per head in 1937 was 12½ cents for 50 or more head and 15 cents for a smaller number

Marketing The methods of marketing mohair vary in different parts of the country and also in respect to the quantity of mohair that any grower has to market Among the more important agencies involved in getting mohair from producer to consumer are the country buyer, the country assembler, the central market dealer, the commission merchant, the broker, and the manufacturer

The small producers in the farm states often consign their mohair to a warehouse for storage and sale In the range country, where production is relatively great, the growers often bring their mohair to these warehouses and either sell it outright for cash or obtain advances on a certain percentage of the market price until such time as the mohair is sold to the mills

The principal market centers of the United States are New York, Boston, Chicago, and Philadelphia The mohair growers also have well-located central points and market centers in the West The mohair grown in Arizona, California, Oregon, and Washington is mostly centralized in San Francisco and Portland, where it is graded and shipped Texas, which produces the largest part of the mohair clip in this country, has several local market points The principal Texas markets are at San Angelo, Del Rio, Kerrville, and Uvalde Mohair is usually sold on samples inspected, and the buyer must deposit a sight draft previous to shipment In some instances mohair may be bought on terms The Pacific coast has a warehouse which classifies mohair according to the tentative grades of the United States into kid, first, second, and third, with stained, burry, and kempy mohair as off-sorts The large users of mohairs divide the first two grades further by sorting The main sorts made in this country and commercially available are super-kid or baby-kid, 40s, 36s and 32s, for kid mohair The first grade is subdivided into 28s, 24s, 20s, and low Some dealers in mohair top use letters such as A, AB, B, C, and CL as designations for their sorts

Turkey and the Union of South Africa are the principal exporters of mohair The present clip in Turkey amounts to about 60,000 bales weighing from 168 to 182 pounds each Practically all of this

mohair enters international trade Constantinople is the principal mohair market of Turkey. The import duty on raw mohair into the United States is based on a rate of 34 cents per clean pound The grades are based, as in wool, on the possible spinning count obtainable using the Bradford system (560 yards per pound).

Turkey mohair As would be expected from the native home of the Angora goat, Turkey mohair is of the very best, being of good length, excellent luster, and clear color Different goat districts supply different classes of hair, i e, Angora, Beybazar, Castamboul, and Van The following list will give some idea of their characteristics:

Fine Districts Length, 6 to 7 inches; luster excellent, color very clear, handle very soft

Beybazar and *Angora* Length, 8 to 9 inches, luster very good, color good, handle soft

Castamboul Length, 8 to 10 inches, luster good, color fairly good, handle fairly soft

Turkey produces also several million pounds of a reddish brown mohair known as Gingerline With the exception of the presence of color pigment the microscopic characteristics are the same as for white mohair

Barker states that the quality of Turkey mohair is not what it once was The deterioration was caused by crossing with the common Kurd goat in an effort to meet the unprecedented demand for mohair fiber by Europe from 1820 to 1860. The Kurd goat yields only a long, coarse kempy hair, mostly used for tent cloth and sackcloth Since 1880, however, the quality of Turkish mohair has improved by breeding back to the true Angora type.

Van mohair, drawn from the district of that name in Asia Minor, is dirty and very dry, though it scours very well; it is specially mentioned in the British Factory Act as a dangerous wool, being more liable than other mohair to contain the deadly germs of anthrax. In fineness, Turkey mohair reaches about 50s quality.

Cape mohair In spite of many difficulties, the Angora goat was successfully introduced and crossed with the South African variety to produce a breed of goats growing a good class of hair. Mohair from the Cape of Good Hope province now bears comparison with the best Turkish qualities, the climate and general conditions of the Cape being very suitable. The color of Cape mohair is not generally so clear as Turkey hair, being of a deeper brown There are two clips a year, summer growth and winter growth The following list shows the principal classes:

Cape kids. The first shear from the young goat, equivalent to lamb's wool Length, 6 to 7 inches, very lustrous, brownish color, and very soft

Cape first The long summer growth Length, 8 inches, very lustrous, fairly clear in color, and soft

Cape winter The shorter winter growth Length, 5 inches, good luster, fairly clear color, and fairly soft

Cape Basuto A class of hair rather stronger and coarser than Cape firsts

Cape mixed A class of hair between Cape firsts and Cape winter, such as a late clip or a mixture of the two clips

Thirds. Equivalent to edges of a long wool fleece Each fleece may be subdivided into firsts, seconds, and thirds, according to fineness, length, and luster

From the foregoing it will be seen that Cape kid mohair is the most valuable product, on account of its extra fineness, and because the supply is small. Cape firsts combine good quality with extra length Cape mohair, in fineness, reaches the same quality number as Turkey hair, viz , 50s

Physical properties The hair of the Angora goat grows in long uniform locks forming a fleece, which gives the animal the characteristic appearance seen in Fig 1 The raw fiber has a yellowish or grayish cast or color, caused by the presence of 15 to 25 per cent of foreign matter, such as sand, dust, and grease The grease content is usually less than 4 per cent After scouring, the mohair shows the silklike luster for which it is mostly valued The best grades are clear white.

Length The length of the fiber ranges from 4 to 6 inches for a half year's growth and 6 to 12 inches for a full year's growth Because of the differences in age of the kids at the shearing time, the fleeces are not as uniform in length as those of the grown goats

TABLE 4

TENTATIVE U S MOHAIR GRADES, FINENESS DISTRIBUTION

	Grades							
Diameters in microns	*Kid* *Fine*	*Kid* *Coarse*	*First* *Fine*	*First* *Coarse*	*Second* *Fine*	*Second* *Coarse*	*Third* *Fine*	*Third* *Coarse*
From								
10 to 20	20	2	5	1	1	1	—	—
20 to 30	71	39	37	26	20	9	2	—
30 to 40	9	59	56	61	35	21	31	5
40 to 50	—	—	2	12	25	22	41	21
50 to 60	—	—	—	—	15	27	18	18
60 to 70	—	—	—	—	4	20	6	30
70 to 80	—	—	—	—	—	—	2	20
80 to 90	—	—	—	—	—	—	—	6
Average	23 98	30 43	30 62	33 23	39 82	47 40	45 13	61 05
Dispersion	11 to 35	14 to 40	15 to 50	15 to 45	18 to 70	14 to 70	28 to 80	35 to 90

Fineness Mohair is graded in some warehouses before it reaches the manufacturer The trade has not yet arrived at a standard which is recognized by all parties, but the U. S. Department of Agriculture has issued a standard for criticism consisting of four grades In Table 4, the fineness distribution is given in per cent, based on the average of testing 100 fibers.

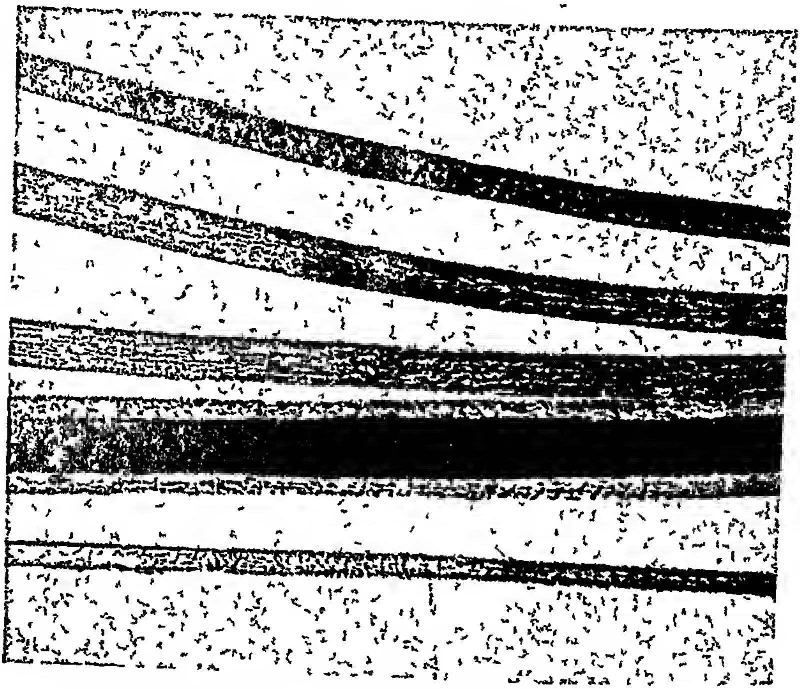


Fig 4 Longitudinal view of mohair fibers (X250)

TABLE 5

FINENESS MEASUREMENTS OF COMMERCIAL MOHAIR TOPS

Grades		*Average (microns)*	*Deviation (microns)*	*Coefficient of Variation (per cent)*	*Standard Error (microns)*	*Average Range (microns)*	*Dispersion Range (microns)*
Super kid	Kid	25.7	6.30	24.5	0.19	25.2 to 26.3	10 to 45
40s	Kid	27.0	5.29	19.1	0.17	26.5 to 27.5	10 to 45
36s	Kid	28.7	6.23	21.7	0.19	28.1 to 29.2	10 to 50
32s	Kid	30.0	6.89	22.9	0.22	29.4 to 30.7	10 to 50
28s	First	32.2	7.81	20.5	0.24	31.5 to 32.9	10 to 55
26s	First	34.0	7.99	23.5	0.25	33.3 to 34.8	15 to 55
24s	First	35.7	9.25	25.7	0.29	34.8 to 36.5	15 to 60
Low	Second	41.4	10.60	25.6	0.30	40.5 to 42.3	20 to 70

Table 5 gives the fineness graduation of eight mohair tops obtained in the Boston market, based on the measurement of 1000 fibers each From these measurements it is evident that the trade already recognizes four grades of kid and three grades of first, with a low equivalent to a second, making a total of eight grades The measurements also prove that the fineness is the main factor governing the sorting of mohair.

Microscopic structure In its microscopic structure the mohair fiber is similar to wool, but it has some characteristics which make its identification possible. The epidermal scales are only faintly visible and hardly overlapped They lie close to the stem, giving the fiber a very smooth appearance The number of scales per 100

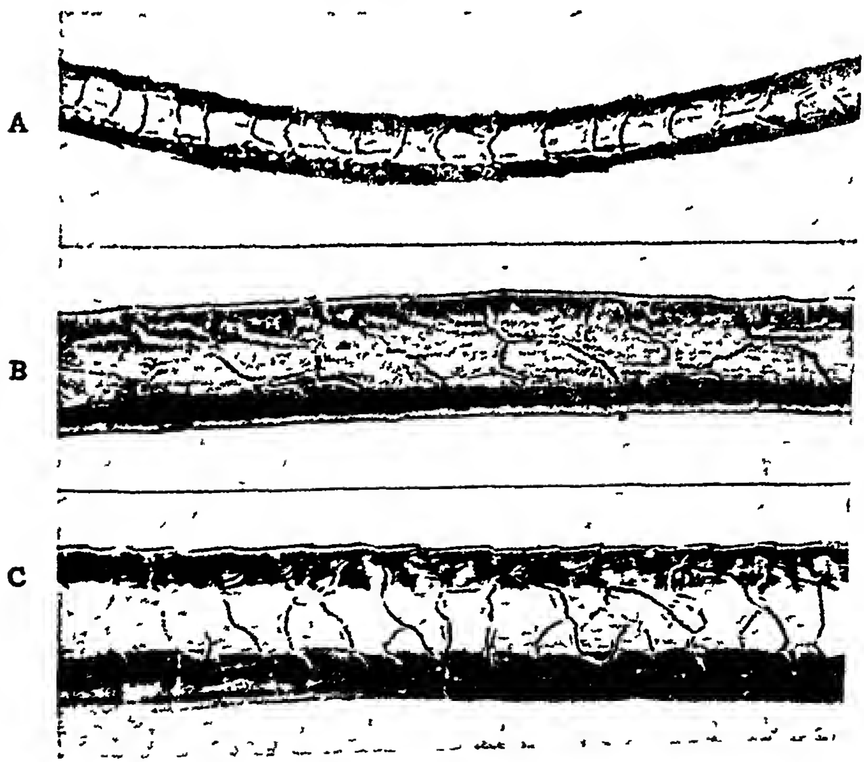


Fig 5 Difference in scale formation of wool and mohair fibers
A—fine wool, B—mohair; C—coarse wool (X500)

microns is five against ten to eleven in fine wools. The scale length ranges from 18 to 22 microns This scale formation is the cause of the smooth handle of the fiber as well as the high luster On the large, uninterrupted fiber surface the light rays are reflected

The cortical layer built up of the spindlelike cells is clearly visible as strong striations throughout the length of the fiber. In many instances, there exist between the cells air-filled cigar-shaped pockets or vacuoles of various lengths The percentage of hairs containing such vacuoles varies within wide limits.

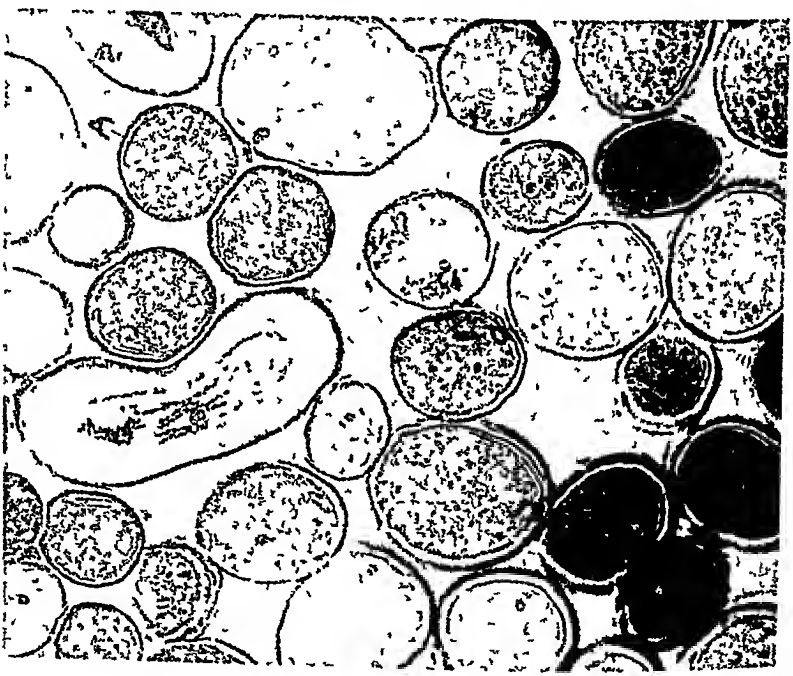


Fig 6 Cross section of kid mohair (X500)

Medullas. The number of medullated fibers in well-bred mohair is normally below 1 per cent In a study made on Texas and Turkish mohair the data in Table 6 were obtained

As in wool, three forms of medullas are found in mohair, namely, (1) continuous, (2) interrupted, and (3) fragmental types The continuous type is most common (See Fig. 4).

Cross section Mohair is recognized immediately by a skilled worker as having a cross section of high circularity. The ratio be-

tween the major and minor diameters is usually 1 1.12 or lower. Many hairs show black dots or little circles, which are caused by the air-filled pockets or vacuoles already mentioned Fibers range in diameter from 14 to 90 microns (Fig 6)

TABLE [illegible]

MEDULLATED FIBERS IN TEXAS AND TURKISH MOHAIR

Samples	Average (microns)	Part	Number of Fibers	Medullated Fibers	Kemp
Texas kid mohair	21	Root	1000	7	—
Texas kid mohair	29	[illegible]	1000	16	2
Turkish mohair	9 in staple	Root part	210	8	6
		Middle part	120	2	—
		Tip	120	—	—

Kemp The manufacturer's great objection to mohair is that it commonly contains short, coarse, undesirable fibers, known as kemp. Besides taking dye poorly, these fibers often cause a loss in combing of as much as 18 per cent of the original weight. In addition, it is not possible to remove them completely from good mohair. In the best Texas mohair, however, the percentage of kemp is negligible

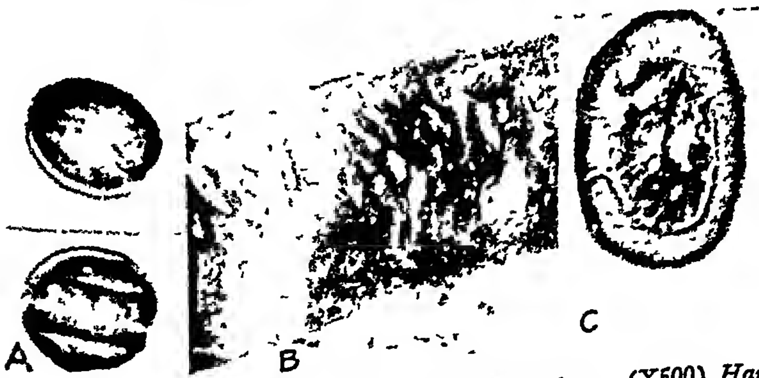


Fig 7 Section of mohair fibers A—normal; B & C—kemp (X500) *Hardy*.

Moisture content The average moisture content of the mohair fiber when exposed to standard conditions is equal to that of wool

Chemical properties Chemically the mohair fiber is identical with wool Its sulfur content seems to vary according to the origin of the mohair Harris found that the sulfur content of Texas kid

mohair is 2.92 per cent and of Turkey mohair fleece 3.58 per cent. In general, mohair is more sensitive to the various chemicals than wool, consequently, more attention should be given to the amount of chemicals used in the various manufacturing processes, such as scouring, dyeing, carbonizing, and bleaching. As with wool, the mohair fibers covering the back of the animal are more or less damaged by sunlight while still on the animal, a damage which influences the dyeing property of the fibers.

Commercial uses. As an upholstery material, mohair—usually in the form of a pile fabric—is unsurpassed for general durability. Mohair fabrics are used for upholstery of automobile and railroad car seats, where the fabric must withstand the hardest kind of service. It is not necessary to sacrifice esthetic properties to gain a high degree of durability, for it is possible to make many beautiful coverings by variations in the pile height and structure, as well as by embossing and hand-block printing.

Mohair is also used in men's summer suitings, in all-mohair fabrics, and in numerous combinations with other fibers, sometimes mixed in the yarn structure, but usually as either warp or filling of the fabric. One of the much advertised brands of men's suitings is made of mohair yarn in one direction and worsted yarn in the other. As a lining for suits, mohair is used extensively, woven plain or twilled, and sometimes combined with wool, cotton, or rayon. In ladies' coatings such as bouclé, mohair blends are especially suitable.

Because of its luster and because it dyes brilliantly and retains the colors well, mohair fiber serves admirably for nets, laces, and drapery materials, and produces many novel effects in decorative trimmings for coats, hats, and shoes. The long lustrous pile is bound into the base of the fabric and then curled and embossed, by ingenious construction and dyeing methods, to imitate furs and to produce materials which are not only attractive but serviceable.

The long-fibered mohair is particularly desired for use in the manufacture of wigs and switches which are used extensively for theatrical purposes. The value of the mohair entering into the manufacture of these products probably represents a larger amount of money for the weight of mohair used than that used in any other branch of the industry.

Rugs of beautiful appearance, with long pile, are made from mohair. The design is frequently effected by hand-block printing

These rugs compare favorably in appearance with handmade oriental rugs. Leather made from the pelt or skin of the Angora goat is useful for ornamental purposes and for the manufacture of gloves, purses, bookbindings, and novelties.

Cashmere

Cashmere hair is obtained from the Cashmere goat (*Capra hircus laniger*), also known as the shawl goat or goat of Tibet. Although the name comes from the Province of Kashmir in northern India, actually the main portion of the cashmere of commerce comes from the northwestern provinces of China, particularly from the provinces of Ningsia, Sui Yuan and Kansu, where the goat is kept as a domestic animal. The hair obtained its fame through the beautiful cashmere shawls made from it in the mountain valleys of the province of Cashmere in northern India.

Fig. 8. Male cashmere goat in Mongolian flock. Ing Hon Kuyang, Sui Yuan Province. *Photo by Burns.*

The animal is somewhat smaller than the Angora goat It has straight, coarse, long hairs and a fine undercoat or down This undercoat alone constitutes the fibers from which the celebrated shawls are made and is known in Cashmere as *pashm* The natural colors of the hair are white, gray or purple and tan, with the gray and tan mixtures prevailing. Every spring the animal loses this undercoat and part of the outer coat through molting, which begins early in June The actual shedding time extends over a period of several weeks

The hair, when loose enough, is combed by hand from the animal During this combing process much of the coarse outer hair, which is not suitable for fine fabrics, is separated from the down. A considerable amount of this coarse cashmere hair is used by the natives for hand weaving of coarse, heavy bags about 5 ft long and 2 ft wide which are strong, durable and water resistant and are used for carrying grain on donkeys' backs The remainder of the coarse hair, not used by the natives, is exported as goat hair

The normal cashmere down consists of a mixture of the fine wool hair with coarse beard hair. The amount of beard hair depends upon the care with which the hand combing was done and may vary from 10 to 50 per cent of the total The yield of this mixture per animal is probably not more than one-half pound

It is impossible to make an estimate of the total number of goats yielding cashmere wool because no data are available Probably the most reliable figures for the amount of cashmere wool produced are those which were given to R Burns in 1946 by the Foosing Trading Corporation, a Chinese Government export trading company The estimated production per annum for the main northwestern provinces of China is as follows:

TABLE 7

ESTIM ANNUAL PRODUCTION OF CASHMERE DOWN IN CHINA

(in pounds)

Province	*Color*	*Amount*
Kansu—Yuen	Purple	66,000
Kansu—Hsinfengcheng	Purple	66,000
Ningsia	White	202,000
	Purple	202,000
Sui Yuan	Purple	172,000
Sinkiang		22,000
Total		730,000

Source R Burns

These figures agree closely with prewar average annual export figures for the years 1934 to 1937 of cashmere down from China, which amounted approximated 850,000 pounds Of this amount, the

United States imported about 350,000 pounds annually. Data reported in the United States Department of State Publication No 2249, "The Livestock of China," are considerably higher, as seen in Table 11. These figures unquestionably include all kinds of goat wool and goat hair.

One of the main collecting centers for cashmere is the city of Lanchow. The original cashmere packages collected from the farmers, weighing about 90 pounds each, are brought by camel train, each camel carrying two packages, one on each side. The cashmere is unsacked, hand or machine dusted and then repacked into bales weighing approximately 175 pounds. When the shipment has been thus prepared, it is transported to the export centers Tientsin or Shanghai, for shipment to the markets.

In normal times the main marketing center is London, although most of the cashmere wool reaching the United States following the close of World War II was handled through the Russian Government agency. The cashmere marketed by the Russians is much lower in quality because it is undusted and unsorted, containing a much higher percentage of coarse hairs. Whereas a good grade cashmere should yield 80 per cent of clean fibers, this undusted product yields only about 50 per cent. A further loss occurs in the dehairing process which may bring the final yield from the poorest quality as low as 20 per cent.

Length. Cashmere wool hair is from 1¼ to 3½ inches long, whereas cashmere beard hair is 1½ to 5 inches. The hairs are con-

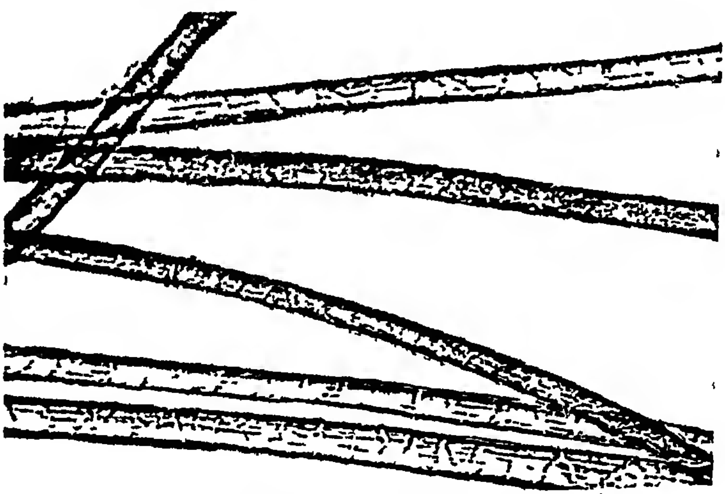
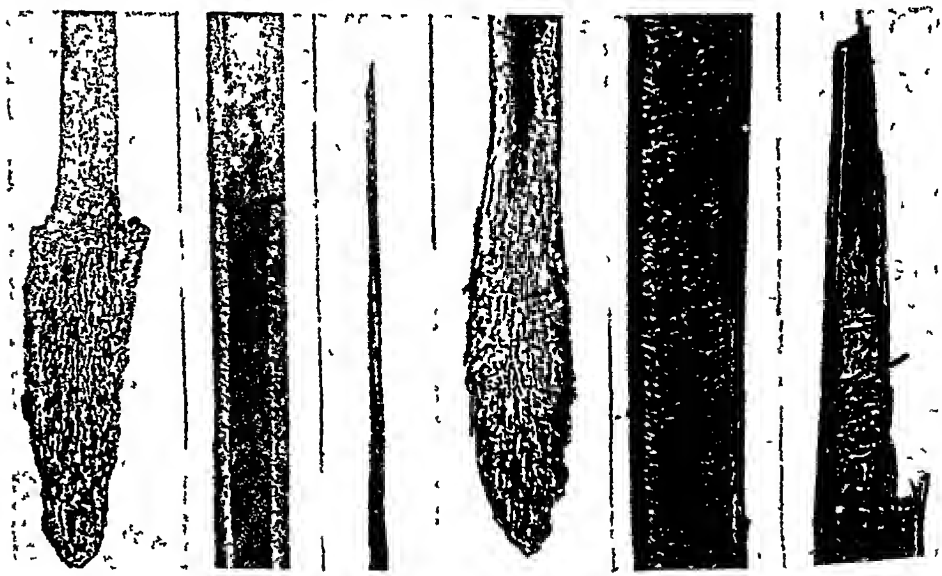


Fig 9 Longitudinal view—cashmere wool hair (X240)

taminated with white scales from the skin of the animal. In the light of a quartz lamp, the cashmere hair has a bluish-white fluorescence, like sheep's wool The scales from the skin show a strong white fluorescence

Microscopical characteristics The cashmere wool hair consists of the cortical layer and the epidermis All the fibers show clearly cylindrical scales which slightly project beyond the cortical layer, causing a serrated effect The number of scales per 100 microns averages six to seven The number of scales is a means of distinguishing cashmere from sheep's wool The cortical layer of white and gray hairs shows distinct longitudinal streaks with crevices between the cells, whereas the brown hairs are covered completely with minute dye pigments (colored granules) Figure 9 illustrates three white and two brown hairs with their characteristic marks



a b c a b c
—White hair— —Brown hair—
a—root, b—middle, c—tip of cashmere beard hairs (X100)
Fig 10 Details of cashmere beard hair

Since the hair is obtained by plucking from the skin of the animal, most hairs retain the root The fibers have long fine ends which, because of their fineness, are already broken on the back of the animal The normal cashmere wool hair grows thinner toward the root as well as toward the end

The fiber is practically circular in cross section; it is, therefore, possible to determine the fineness of the hair from its width without any error. The brown hair shows the brown dye pigment also in the cross section

The diameter of the hair, a true indicator of fineness, is extremely regular with all cashmere wool hairs The values given in Table 8 prove this very well, being based on the measurement of 1000 fibers, except in the last column, where 800 fibers were measured

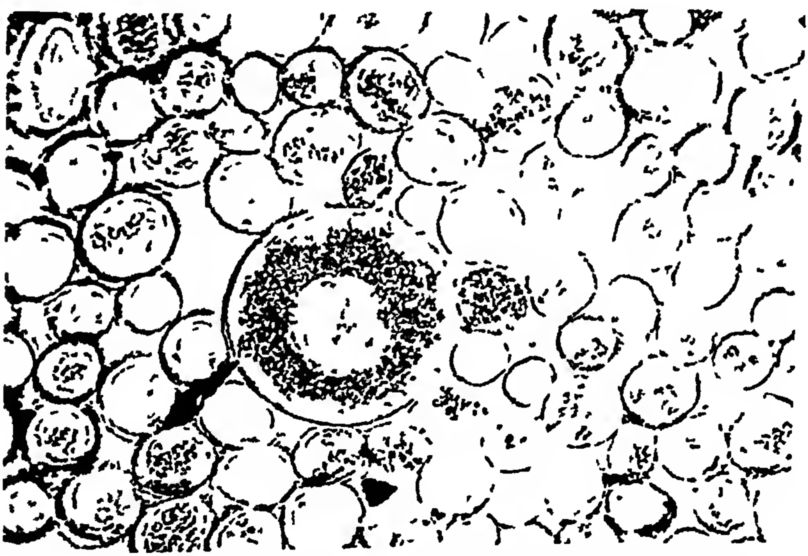


Fig 11 Cross section of cashmere wool hairs and one beard hair (X500)

TABLE 8

FINENESS ANALYSIS OF COMMERCIAL CASHMERE SAMPLES

Type	Scoured Gray	Top Gray	Noils Gray	Noils White	Fabrics of Four Manufacturers
Average diameter, microns	14 8	15 6	15 1	15 1	15 4
Standard deviation, microns	3 0	2 9	2 7	2 9	3 1
Standard error, microns	0 09	0 09	0 09	0 09	0 11
Coefficient of variation, per cent	20 3	18 6	18 0	19 2	20 1

Beard hairs The beard hair consists of three parts, the epidermis, the cortical layer, and the medulla. The medulla on the whole constitutes the larger part of the hair. The root and the extreme end do not contain any medulla Partially medullated hair is rarely found The diameter of the beard hairs is extremely irregular, ranging from 30 to 150 microns with an average of 62 microns

Chemical properties The behavior of cashmere fibers toward chemical influences, as compared with wool fibers, is affected mainly by two factors, the great degree of fineness of the fibers and the better wetting out properties If cashmere is brought under the surface of water, it becomes saturated within a few seconds and lumps together. Wool, on the other hand, must be manipulated for one-half to one minute before the last bubbles of air disappear

Like wool, cashmere is extremely sensitive to alkalies, and, when heated, is completely dissolved by caustic alkalies, such as caustic soda But cashmere is markedly more sensitive toward soda ash than the finest wools The following experiments prove this

Five grams each of carded cashmere and Australian top were treated in 500 cubic centimeters of liquor at 115° to 120° F. for half an hour The different baths contained per 1000 cubic centimeters 1 gram. 3, 5, and 10 grams of soda Table 9 gives the values obtained with this test.

TABLE 9
EFFECT OF ALKALI ON CASHMERE

Content of Soda per Liter in Bath Liquid (grams)	*pH Number*	*Cashmere in Solution (per cent)*	*Wool in Solution (per cent)*
1	9 0	0 22	0 06
3	10 9	0 39	0 17
5	11 0	0 91	0 22
10	11 4	1 39	0 33

As a hair it is chemically identical with wool and mohair. The sulfur content of a sample was found by Harris to be 3 39 per cent and the nitrogen content 16 2 per cent The statement made about mohair being more sensitive toward the various chemicals than wool is true to an even greater extent for cashmere, because of the great fineness of the fiber.

Uses From time immemorial cashmere has been regarded as one of nature's choicest products and unquestionably it is today one of the finest fabrics, for its softness affords the wearer an extrava-

gance of comfort, and its superb soft texture brings to the garment all that may be desired in real elegance and distinction. Owing to the limited number of the animals and the high cost of obtaining the fiber, cashmere is necessarily costly. To produce sufficient yardage for only one overcoat requires the entire animal yield of no less than thirty Cashmere goats.

Cashmere is used mainly for producing high-quality ladies' dress goods and overcoats The most expensive products in this respect are the cashmere silk velour having a silk warp and a 100-per-cent cashmere filling Occasionally cashmere is also used for men's top-coats or overcoats. The percentage of cashmere in the various products varies widely from 100 to 10 per cent. Unfortunately, the word "cashmere" is often used indiscriminately, as many products are called cashmere which actually contain no cashmere fiber at all. Such fabrics can easily be identified microscopically.

Iran goat hair. Hair derived from goats in Persia is occasionally marked as cashmere or Persian cashmere The down is considerably coarser than the genuine cashmere down, running on an average between 19 and 20 microns, which is very close to the fineness of camel's hair Another distinction is its occurrence in such colors as cream, fawn, and dark brown, which are not present in genuine cashmere. In a 20,000-pound shipment the percentages of colors were: dark brown, 30; fawn, 30; white, 10; cream, 22; and light gray, 8.

TABLE 10

FINENESS ANALYSIS OF CASHMERE AND IRAN GOAT HAIR

	Genuine Cashmere	*Iran Goat Hair*
Number of fibers measured	1000	700
Average diameter*	14 8	19 5
Dispersion range*	*per cent*	*per cent*
5 to 10	3	—
10 to 20	92	61
20 to 30	5	37
30 to 40	—	1
40 to 50	—	0 5
50 to 60	—	0 5
Over 60	1	2

* In microns

Common goat hair The hair of the common goat is seldom used in the manufacture of woolen and worsted goods. The coat is largely made up of beard hairs. Like the cashmere goat, the animal goes through a shedding time, and therefore the hair is found mostly with the roots attached The beard hair of the white animals is used in place of kemp as an effect fiber for ladies' sport clothes. This hair ranges in fineness from 7 to 20 microns for the down, from 50 to 200 microns for the beard hair of the full-grown animal, and from 15 to 90 microns for the kid. It resembles cashmere closely That China is the largest source of goat hair and goat wool (cashmere type) is seen from its export figures in Table 11.

TABLE 11

AMOUNTS OF GOAT HAIR AND GOAT WOOL EXPORTED FROM CHINA

Goat Hair		*Goat Wool*	
Year	*Pounds*	*Year*	*Pounds*
1925	3,118,060	1915	1,366,200
1930	1,206,920	1920	1,111,440
1935	2,990,020	1925	3,094,960
1940	1,567,060	1930	1,654,180
		1935	2,628,780
		1940	1,821,600

Source Phillips Johnson Moyer, *The Livestock of China*, U S. Department of State Publication No 2249, 1944

Camel Hair[2]

The camel's hair used in the American wool industry is grown chiefly in Mongolia, Chinese Turkestan, and the Chinese northwestern provinces The camel bred in north China and Mongolia is of the Bactrian type with two humps, as distinguished from the dromedary, or the one-hump camel (see Fig 12).

The ancestry of the domestic camel is unknown, but neither the Arabian nor the Bactrian exists any longer in the wild state, though there are some semiwild herds which have escaped from captivity. Wild camels are said to have existed in Arabia at the start of the Christian era This coupled with the fact that camels do not appear to have been known to the ancient Egyptians makes an Asiatic origin of both types plausible.

[2] Streock, S 1, *The Story of Camel Hair* (1936)

The first person, perhaps, to make a systematic study of the Bactrian camel of Asia, of its fine hair, and of its probable relation and importance to fine and beautiful fabrics was an English Army officer of India, Captain Thomas Hutton In his travels and studies he discovered that the hair of neither the dromedary nor the pure Bactrian camel of antiquity possessed the dual characteristic of warmth against cold and coolness in the face of heat The ancient Bactrian, he found, could not stand heat, and the dromedary was equally at a disadvantage in cold climates But he did learn that the age-old crossbreed of the two camels, producing great herds of the hybrid, or Bokhara type, known natively as the Boghdi, had for thousands of years possessed their individual and rare combination of heat-resisting, cold-resisting shaggy coats of hair Today this Boghdi or crossbred native of ancient Bactriana is the generally known Bactrian camel of Asia

The Bactrian is found in nearly all desert regions of central Asia lying between Afghanistan, Turkestan, China, and southern Siberia, where it is as important to the nomad inhabitants of this region as the Arabian camel is to the Arabs It feeds chiefly on the bitter plants of the steppes, which are rejected by most other animals, and has a curious partiality for salt, drinking freely of brackish water and salt lakes The young are so helpless at birth as to be unable even to eat for about a week; they do not attain their full size and vigor before the fifth year

Fig 12 Bactrian camel Gobi Desert, Mongolia. *Courtesy American Museum of Natural History*

Fig 13 Mongolian camels drinking at well *Courtesy American Museum of Natural History*

The two attempts to introduce camels in the deserts of the southwestern United States as domestic animals have failed The first herd, procured by the United States government from Smyrna in 1856, was distributed over Texas, Arizona, and New Mexico During the Civil War all of these animals fell into the hands of the combatants and were used for carrying mails, some of them making journeys of more than 120 miles a day After the war, the remnant was once more taken over by the federal government, and others were purchased in 1866 These were distributed through Arizona and Texas for breeding purposes, but many died The remainder were turned loose and every now and then there appears a newspaper account of somebody having seen one It is improbable, however, that any of them exist at the present time.

Once a year the better kind of camel's hair is gathered from the living animals in the molting season in late spring or early summer It is interesting to note the manner in which the hair is obtained, being neither sheared nor plucked, as with other fleece-bearing animals In the spring, as the temperature grows milder, the hair begins to form matted strands and tufts, hanging from head, sides, neck, and legs, from which it falls off in clumps By the time warm

weather has definitely set in, the animal has almost completely lost its coat

Photographs of caravans often show a man trailing the last camel He is the "trailer." It should be observed that the animal sheds its fleece not only in the spring, when the greatest quantity is shed, but the year round it is rubbing off chunks of hair The task of the trailer is to pick up the hair as it drops from the camel and place it in baskets provided for that purpose These baskets are strapped to the last camel in the caravan, and therein is transported the accumulation of the entire journey. The hair is also to be found in the morning at the spot where the caravan rested for the night the camel rubbing it off. Where batches appear ready to fail, they are pulled free and stuffed into the baskets The first town reached by the caravan is usually where the hair is sold, generally to traveling compradores who, in turn, forward it to the terminals across mountain and desert Eventually the hair is brought to Tientsin, or to other points of shipment, where it is sorted and graded preparatory to export

The average yield of hair from each animal per year is about 5 3 pounds In 1930 it was estimated that there were over 1,000,000 camels in the regions mentioned Paotowehen and Kweihwa, on the Peking-Suiyuan Railway, are the chief collecting centers for north west China provinces of Ningsia and Kansu with an estimated production of one million pounds in 1946

Table 12 gives an idea of the size of the camel's-hair market

TABLE 12

EXPORT AND IMPORT OF CAMEL'S HAIR

[In thousands of pounds]

	1934	*1935*	*1936*	*1937*
China export	2094	3641	2338	1404
U S import	206	586	526	307

Marketing of camel's hair The camel's-hair trade is dominated by English interests, and most of the hair is shipped directly to London, which is the main marketing place The hair is marketed either in its loose raw form or in semimanufactured products such as camel's-hair top and camel's-hair noils The trade grades are fine, medium, and coarse or qualities 1, 2, and 3

The camel carries a mixed fleece similar to the Cashmere goat. The outer hair of the animal is very coarse, tough, and wiry. It may reach a length up to 15 inches. Beneath the outer hair is a short, soft down of great fineness which varies in length from 1 to 5 inches. The soft down fibers are the valuable product known as *camel's-hair wool*. As the camel loses both coats together during the shedding time, it is very difficult to separate the hairs from the wool fibers. A separation to the extent effected in cashmere is not possible, because a high percentage of heterotypical fibers is present. The type with the thickened tip predominates. The sudden need for a covering after the shedding is probably the stimulating factor for producing hairy medullated fibers, especially with the severe climatic conditions prevailing in Mongolia and Siberia. The best way to separate the down from the hair is through the combing process. In the combing machines the two types of hair are separated, the coarse and long hairs producing the top and the short fibers combing out as noils. The trade grades are based on the amount of coarse fibers still present. The fine camel's hair consists mainly of fine down or camel's-hair wool, of a very characteristic light, reddish brown color. The fineness analysis of a 15 inch staple is an excellent illustration based on the measurement of groups of 100 fibers, shown in Table 13.

Microscopical characteristics. The wool fibers are uniform in width and range from 9 to 40 microns. The epidermal scales are

TABLE 13

FINENESS VARIATION IN A 15-INCH CAMEL HAIR STAPLE

Position in staple from root (inches) Average diameter (microns)	1½ 25.1	6½ 49.5	11½ 72.5
Dispersion range (microns)		*Per cent*	
10 to 20	23	—	—
20 to 30	64	5	—
30 to 40	9	26	—
40 to 50	2	34	1
50 to 60	2	12	4
60 to 70	—	14	19
70 to 80	—	2	20
80 to 90	—	7	21
90 to 100	—	—	22
100 to 110	—	—	13

poorly visible The diagonal edges of the scales are more or less sharply bent The cortical layer is regularly striated and filled with color pigments Some hairs show interrupted medulla The presence of these medullated fibers and the wider dispersion range are the characteristics that identify the fibers Beard hair is dark brown to black, 30 to 120 microns broad, with a wider and mostly continuous medullary cylinder The thin fiber layer contains strong accumulations of dark brown to black granules The medullary cells are short but broad, and are filled with color pigments

The data in Table 14 illustrate clearly the variation in fineness of commercial camel hair of the various grades

Chemical properties Raw camel's hair contains on the average 15 to 25 per cent sand and dust, and 4 to 5 per cent fat, 75 to 85 per cent is fiber Harris established the sulfur content at 3 47 per cent and the nitrogen content at 16 48 per cent for purified camel's hair

Fig 14 Camel hairs Longitudinal (X240) and cross sections (X500).

TABLE 14

FINENESS ANALYSIS OF COMMERCIAL CAMEL'S HAIR

Types	*Scoured and Carded*	*Top*		*Noils*		
		Fine	*Coarse*	*No 1*	*No 2*	*No 3*
Number of fibers	1000	1000	1000	1000	500	500
Average, microns	19 7	18 2	23 1	18 0	20 9	22 8
Deviation, microns	6 60	5 48	9 46	5 38	7 75	9 31
Stand error, microns	0 21	0 17	9 30	0 17	0 34	0 42
Variation, per cent	33 4	30 1	40 9	29.9	37.1	40 8
Dispersion, microns	10 to 45	6 to 40	10 to 55	8 to 40	8 to 50	10 to 55

These amounts are nearly identical with those found in cashmere and mohair It is therefore logical that camel's hair shows the same behavior toward chemicals as the two previous specialty hair fibers

Uses Camel's hair has found its greatest use in men's high-grade overcoating. Because of their high insulating properties, these fabrics are especially preferred by Arctic explorers Probably no other fabric is as badly misrepresented in the market as camel's hair The public is becoming more and more conscious of this fact and is insisting on properly labeled goods The characteristic tan color does not ensure the consumer against buying a cheaper substitute because the color can very easily be matched by any experienced dyer A proper microscopic analysis is the only way to disclose the real presence of the camel's hair

The Llama Family[3]—Auchenias

The llama constitutes one branch of the small family of animals known as the Camelidae, the Old World camels constituting the other branch of the family Whether camels and llamas are the descendants of a single progenitor has not been definitely established, but the discoveries of fossil forms of the true camel in various parts of this hemisphere seem to lend strength to the contention. The two branches, however, are now quite distinct

Today four distinct and two hybrid species of llamas exist, and all are confined to the Pacific coast regions of South America,

[3]Stroock, S I, *Llamas and Llamaland* (1937) Hodges, W H, *Camels of the Clouds*, The National Geographic Magazine LXXXIX, 5, pgs 641-56, May 1946

occurring chiefly in the inaccessible regions of the high altitudes These species are llama and alpaca, the domesticated members of the tribe, guanaco (or huanaco as it is known in Peru) and vicuña, the wild members The hybrids are huarizo, known to the Indians as *huaro*—progeny of a llama father and alpaca mother—and paco-llama, or *misti* in Quichua, the language of the aborigines—offspring of an alpaca father and a llama mother Unlike most hybrids, these two animals are productive, but after a few generations they usually revert to type. The vicuña and the alpaca have also been crossed to produce two other hybrids, paco-vicuña and vicuña-paco, depending on whether the father was alpaca or vicuña The intention of this interbreeding was, of course, to produce an animal that would combine the stature and heavy fleece of the alpaca with the magnificent hair of the vicuña But these expectations were not realized, and today these two hybrids are practically extinct

There has always been a good deal of confusion as to the origin and classification of the various llamas, but today scientists are in general agreement that the llama and the alpaca are the direct descendants of the guanaco, and the vicuña is a distinct species No doubt a long period has elapsed since their evolution, for both the

Fig 15 Peruvian llamas *Courtesy Ewing Galloway, New York*

llama and alpaca have been domesticated for probably 1200 years, and today there is a pronounced difference between the wild and domesticated species in both physical characteristics and behavior

The habitat of all the llama tribe, except the guanaco, is the high Andean regions of southern Ecuador, Peru, Bolivia, and of northwestern Argentina The guanaco once roamed the pampas and other open areas from Ecuador to Patagonia (southern Argentina), including all the above-mentioned countries, and Chile, but today it is confined chiefly to Patagonia It is also seen in the rocky islands to the south of the Strait of Magellan

The Andean mountain system has two principal chains, the western, or Cordilleras, situated 60 to 75 miles from the Pacific, and the eastern, or Andes proper, paralleling it, but with a slightly eastward slant Between these two chains lies the *puna,* the vast almost uninhabitable 300-mile wide tableland that stretches from southern Ecuador to the Argentine This plateau is not absolutely arid, however, for upon it are found various mosses and lichens, including the grass *ichu,* chief diet of the various llamas and a few stunted trees and bushes Their growth is made possible by the moderately heavy precipitation during the rainy season (from late November until about the middle of April) and, to some extent, by the thick mists that intermittently sweep down from the mountain heights

The llama, *Lama glama glama,* is the largest of the Andean Camelidae, weighing about 250 pounds and being approximately one-third the size of the Old World camel The body, which tapers like that of the greyhound, is about equal in length and height, giving the animal a finely proportioned and exceedingly graceful appearance The llama stands 4 to 4½ feet high, although occasional specimens attain a height of 5 feet

The llama has a thick coarse coat, which terminates abruptly along the bottom line of the body Its long neck is well covered, but its throat is bare Its fleece is valuable as fur and is erroneously known in the fur trade as vicuña fur The hair closely resembles that of the alpaca, with a mixture of fine hairs and kemp

Although of variegated colors, the llama fleece has a tendency to run to browns Some fleeces are lighter, of course, some are pure brown and others are black; some are pure white or a mixture of colors The hair under the belly is generally white

The llama's economic importance is as a burden carrier, and apparently always will be, for today the llama remains the only reliable draught animal of the upper Andes, it is able to live at alti-

tudes of over 2½ miles above sea level without being subject to mountain sickness.

There are about 2,000,000 llamas in Bolivia today, and probably a little less than half that number in Peru, with another 100,000 distributed throughout the higher areas of Ecuador, Chile, and Argentina They are owned almost exclusively by the Indians, who alone appear able to understand and manage them

Alpaca[4]

Equally as important and surely of more specific importance to the textile industry is the alpaca, *Lama glama pacas,* the second of the domesticated species. This animal has always occupied a major position in the economic life of the great Andean plateau It was indispensable to the general welfare in both Inca and pre-Inca days and has been almost equally so in the centuries that have intervened Even today, although the sheep of the lower altitudes have increased immeasurably in number, its position as a fleece bearer is unchallenged (See Fig. 16)

Physical characteristics The alpaca is somewhat shorter than the llama, seldom being more than 3½ feet high Its body, however, is proportionately larger, and of greater bulk Like the llama, it is variegated in color, with grays and fawns predominating. Sometimes it is of a coffee color, sometimes pure white or black, and not infrequently piebald Its soft fleece is remarkably beautiful, fine and strong The average weight of the animal is 175 pounds

The hair of the alpaca hangs down its sides, rump, and breast in long, glossy, and more or less tangled strands, measuring from 8 to 12 and, not infrequently, 16 inches in length, and when left unsheared for long periods it attains lengths of nearly 30 inches This hair differs from that of the llama in having no coarse or brittle fibers, which are common in the fleece of the llama It shears from 4 to 8 pounds every second year

There are two distinct breeds of alpaca, the *huacaya* (or bacaya, as it is called in some districts) and the *suri* The huacaya is bigger than the suri, heavier in weight, and in a general aspect more closely resembles the llama. The suri, however, produces a fleece that is finer, more lustrous, and thicker. The comparative weights of the fleeces yielded by these animals are. huacaya 5½ pounds, suri 6½ pounds, for the same period of growth and the same length of staple

[4]Alberts, H W, *American Consular Report No* 305, July 1944, Lima, Peru

In 1944 it was estimated that there were 2,000,000 alpacas in Peru, 50,000 in Bolivia and a small number on the high plateaus of Argentina and Chile. Neither Peru nor Bolivia has ever made a census of the animals, so it is impossible to estimate the number of heads with any degree of accuracy.

The alpaca does not thrive in regions lower than 12,000 feet, being in its own element in the lofty regions of 13,000 to 16,000 feet. It often ascends to heights of 17,000 feet or more, just below the snow line The animal is not found north of the equator because of the absence of the grass *ichu,* its principal source of food. Nor has its acclimatization been found possible elsewhere, although attempted in various parts of the world, notably in England and Australia. Further efforts, however, are not likely to be made in the future, for under a law enacted by the government of Peru, the animal's exportation is now rigorously prohibited.

Until shearing time, the alpacas roam the limitless range throughout the day, and in the evening return to their corrals, dilapidated structures of stone for the most part, many of them antedating the

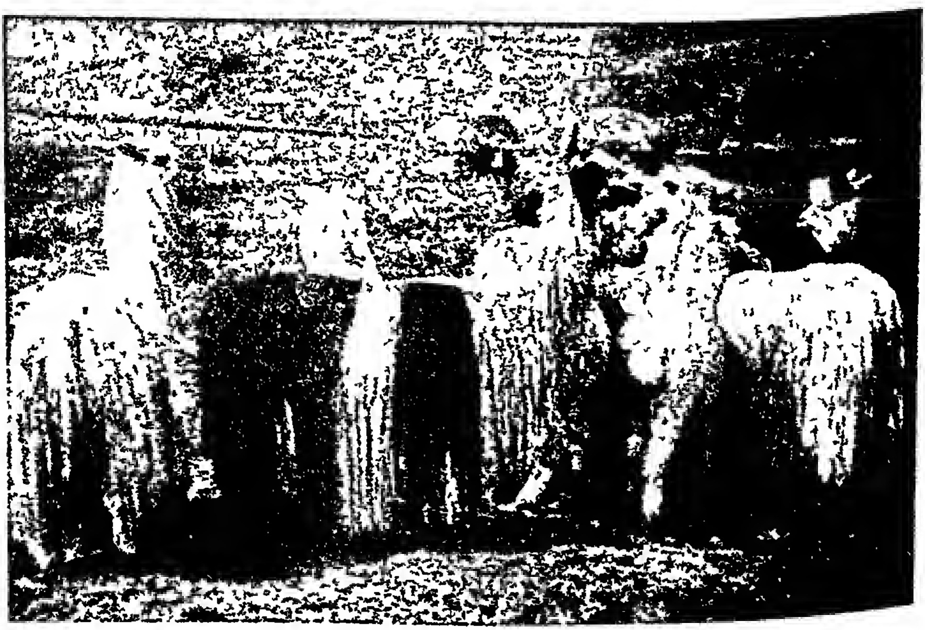


Fig 16 The Suri, finest breed of alpaca *Courtesy of S I. Stroock.*

Inca's regime The sixth sense of the alpaca is uncanny, and the flock knows instinctively when the time has come to follow the leader, called *haino* by the Indians, to the fold, unfailingly they return on the minute The reason for enclosing the flocks at night is to obtain the excrement, the principal and, before the coming of the railroad, the only fuel of the puna. This product of the alpaca finds its chief use in the mines

Efforts to raise the alpaca on a large commercial scale have been made from time to time, but invariably without success A few years ago, for example, a British company leased thousands of acres from the Peruvian government for this purpose, expecting to raise the alpaca as sheep are raised, but the enterprise failed

Hybrids of llama and alpaca—huarizo and misti Being members of the same family and endowed with the same instincts and habits, llamas and alpacas mix freely, and out of the association come two hybrid animals, each possessing certain of the characteristics of both animals As has been stated, these animals are huarizo, born of a llama father and an alpaca mother, and misti, the progeny of an alpaca father and llama mother In some remote regions, the huarizo is employed as a beast of burden, but the misti is never so used The fleeces of these hybrids are not as fine, generally speaking, in either texture or quality as that of the alpaca

Fleece production All of these animals produce a certain amount of fleece, but by far the preponderant portion is derived from the alpaca, which, in 1935, accounted for 93 per cent of the total Peruvian clip of approximately 8,200,000 pounds This included first, second, and inferior qualities The actual figures were alpaca, 93 per cent, huarizo and misti 5 per cent, and llama 2 per cent The amount of fleece actually available for any manufacture of fine fabrics, after eliminating inferiors, approximated only 4,000,000 pounds per annum in recent years From 1938 to 1942 the total annual export from Peru amounted to approximately 7,100,000 pounds, of which 88 per cent was alpaca, 8 per cent huarizo and 4 per cent llama

The puna country stretching north and northwest of Lake Titicaca in an almost illimitable sweep is the chief fleece region, the most important collection points being Cusco, Sicuani, Checacupe, Santa Rosa, Juliaca, Ayravire and Puno, the fiber obtained from the last-named town, however, is not considered of high grade Eventually all of these fleeces are shipped to Arequipa, via Cusco and Puno, for grading and sorting for color, after which they are baled for export to the markets of the world Arequipa, a city in southwestern Peru,

Fig 17 The Huarizo, born of Llama father and Alpaca mother
Courtesy of S I Stroock.

is situated at an altitude of 8,000 feet, about 100 miles from the port of Mollendo.

Shearing The alpacas are sheared during the warmest months of the year, late November and early December, just after the rains Until recently, shearing was done in a most primitive manner by cutting the wool with knives, but at the present time shears are being used.

The fleece arrives in Arequipa in bulk, having been turned in and wound up into small bundles, resembling hanks, for easier trans-

position. As the sacks are emptied, the fleece is examined very carefully to see that it has been properly represented for grade and that it has not been "loaded," a time honored practice of increasing weight. The procedure here is to dampen the fleece and load it with sand which, when it dries, adheres to the fleece and becomes like clay in effect. The fleece is then weighed, after which it is sorted for color, each color being piled separately for later careful sorting. In this preliminary sorting the seven basic colors are obtained. They are white, fawn, gray, light brown, dark brown, black, and piebald. After the alpaca fleece is sorted, it is put up in the form of "bumps" and sent to the press for baling. Each bale weighs 100 kilos, or 220 pounds. Llama, huarizo, coarse fleeces, and short pieces are handled separately.

Of the total yield of llama fleeces, including the various grades, it is estimated that more than 80 per cent passes through Arequipa to the port of Mollendo, Peru. The remainder, shipped from Callao and Tacna, other Peruvian ports, is known as Callao fleece and

Fig. 18. Sorting fleeces at a lavadero in Arequipa, Peru. *Courtesy of S. I. Stroock.*

Tacna fleece These are inferior in quality and poorly sorted The packers put these various colors into lots of 100 bales each The approximate percentage of the various colors present in such round lots is: white, 12 per cent; piebald, 10; light fawn, 13 to 14; light brown, 13 to 14, dark brown, 21; gray, 20, and black, 10 In order to get rid of all the colors, the packers will not break up their round lots and sell separate colors

In the period from 1938 to 1942, Peru exported a yearly average of 6,230,000 pounds of alpaca, 320,000 pounds of llama, 91,000 pounds of short huarizo and 470,000 pounds of fine huarizo wool

Vicuña

Vicuña wool is obtained from the smallest and most agile species of llama, the vicuña (*Lama vicunna*). It is the rarest and finest fiber classified as wool and is therefore very much sought after.

The wild vicuñas, valued for their wool and meat, had been hunted by the Indians since remote times. Before the Spanish Conquest, hunting was regulated under strict surveillance by the Incas or Indian rulers Only once in every 4 or 5 years was a hunt (or chaco) organized and was always accompanied by a great celebration Hunting by individuals was prohibited Only the Inca, his family and some persons of high rank could use the skins and the wool Under this regulated system of hunting, the animals maintained their numbers So far as is known, the Indians never domesticated them

During the colonial period under the Spanish regime, the chacos were conducted without order or regulation They were repeated frequently, killing not only the males but also the females and young animals Firearms were used also, resulting in depletion of the flocks to such an extent that the species was facing extinction

In 1825, shortly after the declaration of independence, the liberator, Simon Bolivar, had two decrees promulgated prohibiting the killing of vicuñas, and permitting them to be sheared only in May, June and July in order that the mildness of climate might substitute for the lack of wool. A fine for violation of the decree was provided The domestication of vicuñas was encouraged by the offering of a reward for each vicuña domesticated This offer extended over a period of ten years Twenty years later the production of alpaca-vicuña crosses was encouraged

Because of considerable illegal traffic in skins and animals, a resolution was issued in 1898 reinstating the decrees of 1825 In 1907, hunting of the animals was restricted and in 1920 the manufacture of vicuña cloth and the manufacture of articles from vicuña wool and skins

was prohibited. Exportation of vicuña wool and the sale of articles made from vicuña wool was prohibited in 1926 This so discouraged efforts to raise vicuñas that in 1936 a decree was promulgated which permitted the raising of vicuñas under domestication and the sale of wool under governmental supervision

The animals are found in the wild state throughout the Andes mountains of Peru, their greatest concentration being in the Departments of Puno, Cuzco, Apurimac and Arequipa They are found also in the mountain areas of Bolivia, in the extreme northern part of Chile, and in small numbers in the Province of San Juan, Argentina In 1946 it was estimated that there were approximately 50,000 vicuñas in Peru

Fig 19 The Peruvian Vicuña.

The habitat of the vicuñas is at elevations of from 13,000 to 16,500 feet, where climatic conditions are not extremely variable They abound where short grasses are found in the high damp prairie areas known as *bofedales* Although they usually live at higher elevations, they are often found grazing in flocks with alpacas and llamas

Smaller than its three relatives, vicuñas stand less than 3 feet high and weigh from 75 to 100 pounds They are the most timid as well as the most graceful in appearance, having a fine, slender form (Fig 19) Their bodies are covered with a short wool On the necks of the animals, it has the appearance of fine down On the flanks toward the chest and belly, the exquisitely soft coat is much longer and

of a light cinnamon, known as vicuña, color. The color shades to a pallid white on the belly and the inside of the thighs, but this wool does not have the same length or degree of fineness as the rest. Between the chest and forelegs, almost down to the knees, and continuing along its flanks, are fringes of long white hair which form an apron, giving the vicuña a distinctly characteristic appearance. The apron is accentuated in the males. The vicuña differs from the other three species also in having no callosities or bare spots on its hind legs.

Prior to strong government control, the wool was used by the Indians in weaving panchos, scarfs and sweaters, which have now disappeared from the market. Bedspreads were made from the skins of the neck and legs. The natives used the meat in the form of charqui or dried meat.

The amounts of vicuña wool exported during the period 1933 to 1941, illustrate the rarity of this fiber. (See Table 15.)

TABLE 15—VICUNA WOOL EXPORTS

	Countries of Destination			
Year	*Great Britain*	*United States*	*Italy*	*Total In pounds*
1933	1,107			1,107
1936	3,881	1,173		5,054
1938	1,916	1,379	132	3,427
1939	246	1,173		1,419
1940		7,995		7,995
1941		906		906

The prices in Peru fluctuated: in 1933 the wool sold for approximately $10.00 per kilo; in 1936, $7.00 per kilo; in 1938, $7.50 per kilo; in 1939, $7.50 per kilo; in 1940, $9.50 per kilo, and in 1941 $10.00 per kilo (1 kilo = 2.2 pounds). In Peruvian money a kilo in 1941 cost 21 soles; 1 sole is equal to $.474.

Vicuñas can be domesticated only when captured very young or when they are born in the fold. Numerous attempts have been made at domestication, but only recently has it been a comparative success. Although the Peruvian government has encouraged domestication of vicuñas for a long time, only a few persons have done so. One of them, Francisco Paredes, has accumulated a considerable flock. He began his work in 1919 when he captured five young animals. In the latter part of 1943, his flock consisted of more than 300 animals, which comprised 20 breeding males, 60 castrated males, 45 young males, 48 young unbred females, 80 breeding females and 62 young offspring.

Mr. Paredes began shearing his animals in 1938, obtaining annually an average of 6 to 8 ounces of wool per animal.

Crosses occur under natural conditions when male vicuñas mate with

female alpacas The offspring of alpaca-vicuña matings are known as paco-vicuñas Their wool is an improvement over that of the alpacas being fine, silky and long, but after the first shearing, the wool loses its fineness and the daglocks, which comprise the wool of the legs and chest, develop strongly The hybrids are taller than the vicuñas and very resistant to cold.

There are two governmental projects in Peru on which work on vicuñas is being conducted One is located at the Granja Modelo de Puno at Chuquibambilla and the other at La Raya between the Departments of Cuzco and Puno The Granja Modelo de Puno is an official technical dependency situated in the Province of Melgar, 13,000 feet above sea level In 1943 there were 28 animals, four of which were born at the station that year

In 1943 a farm was established with headquarters at La Raya to study the system of pasturing, selection of breeds, crosses, diseases and other problems concerned with raising auchenias which include vicuñas

In June 1945, the Peruvian Government promulgated a law, number 10,189, which charges the Ministry of Agriculture with the task of studying ways and means of improving auchenias and to sponsor, especially, the campaigns conducted for the breeding and domestication of vicuñas The monetary means for carrying out the measures are provided from a tax levy applied to all classes of wool, including imported wools, amounting to 2½ per cent ad valorem Of this money, one-fourth is used for the support of a model auchenia farm

Under present laws in Peru and neighboring countries the vicuñas are increasing It is not uncommon to see as many as 10 to 15 flocks in crossing the mountains between Arequipa and Juliaca If the present system of raising vicuñas under domestication proves to be successful, the number of animals can be increased enormously The area suitable for raising them is extensive

TABLE 16—ALPACA, VICUÑA, LLAMA AND HUARIZO IMPORTS FROM PERU BY THE UNITED STATES

(in the grease in thousands of pounds)

	1938	%*	1942	%*	1943	%*	1944	%*
Alpaca	1,237	19	4,084	80	5,235	89	6,295	94
Vicuña	1	33	0	0	0	0	0	0
Llama	0	0	177	72	190	79	142	92
Huarizo	11	24	195	39	429	80	455	95
Total	1,249	17	4,456	76	5,854	88	6,892	94

* Of total export The remainder of the Peru export went to the United Kingdom, Germany and Belgium

Source Alberts, H W, Amer Consular Report 313, July 1944, Lima, Peru

Unquestionably the steady demand for vicuña wool in the United States and the great publicity given to the fibers have convinced the Peruvian Government that its export on a large scale would be a very worthwhile source of income for the State

Guanaco[5]

The fibers of the guanaco (*Lama huanaco*) have only recently been introduced by the woolen industry as one of the luxury fibers The guanaco is thought to be the original stock from which came the llama and the alpaca It is smaller in size than the llama never growing to a height of more than four feet, but is larger than either the alpaca or the vicuña

Fig 23 Guanacos *Courtesy New York Zoological Society*

In general the guanaco is scattered over a much larger territory than the other auchenias It is found in its wild state as far south as the Straits of Magellan It seems that the animal has migrated southward because, in the llama land proper, it is very rarely found. It is quite

[5] Bachrach M , Fur, 1936

plentiful in Patagonia where the animal furnishes the natives with food and raiment

Although it resembles the llama somewhat in its outer form, the back of the guanaco is more arched and its body is less tapered at the waist Guanacos are by far the swiftest of the four species, are very shy and travel in small herds The mixed coat is rather shaggy but the down is of unusually fine texture The color of the wool is reddish brown on the upper and white on the lower portions of the body, much like the vicuña, but the white area is larger. The pelts, especially the baby guanaco, known as guanaquito, resemble those of the red fox Some of the peltries taken in Chubut are very red; in fact almost copper-color.

Argentina is the principal source of guanaquito furs and the guanaco fibers used in the woolen industry are obtained from Argentina peltry by the cutting and blowing process described under rabbit hair The peltry of the guanaquito is used for trimming cloth coats Their use for fur purposes is possible because the hairs of animals a few weeks old are rather straight and lack the wooly texture The best grade of peltry is that which, in general, resembles the fox and in which the beard hair is similar to the guard hair and the fine down, the fur fiber The peltries are known by the names of the collecting sections These sections are: Rio Gallegos, Chubut, Punta Arenas, Rio Negro, Santa Cruz, and Pampas The finest type of peltry is produced in the Rio Gallegos district which extends from southern Santa Cruz southward to the Punta Arena area

There has been confusion about the proper name of this peltry because certain concerns in the trade have adopted the name *vicuña* for it This name is naturally misleading when used for the fibers cut from the guanaquito peltry.

The hair is a mixed type containing approximately 10 per cent beard hair Microscopically, the guanaco is similar to vicuña, the only difference being in the fineness and color Fineness measurements made on guanaco fibers place it between the alpaca and vicuña Fiber width averages vary from 18 to 24 microns Fineness analyses of various guanaquito and baby vicuña samples obtained from living animals in the New York Zoological Garden, from Argentinian pelts and from commercially prepared cut and blown samples gave the results shown in Table 19 The results show clearly the difference which exists in regard to fiber distribution in vicuña and guanaquito They also indicate that baby guanaco born in New York carries a coarser fleece than that normally found in the Argentina animal The same is true of baby vicuña, the average fiber diameter of that born in New York being

nearly 2 microns coarser than that of the Peruvian animal Guanaquito is comparable in fineness to 80s wool, but its physical structure makes it much softer and more lustrous

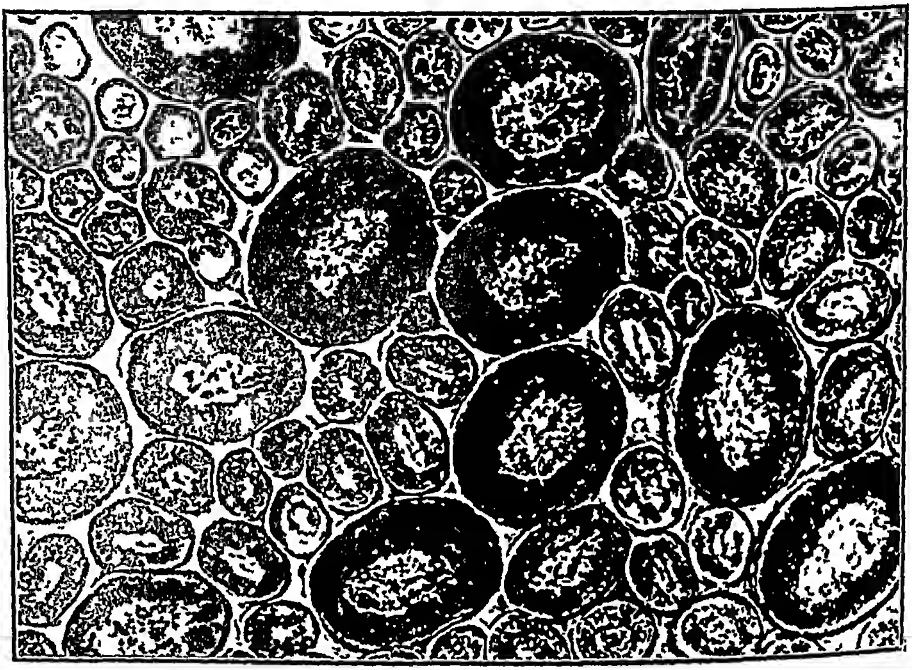


Fig 24 Guanaco cross section (X500) *Courtesy Forstmann Woolen Co*

TABLE 19—FINENESS ANALYSES OF GUANAQUITO AND BABY VICUÑA FIBERS

	Guanaquito		*Baby Vicuña*	
	Commercially Prepared (cut and blown)	*Argentina Skin*	*New York Zoo*	*New York Zoo*
No of Fibers	400	400	400	400
Per cent of fibers from				
0-10 microns	1 0	3 0	0 5	2 0
10-20 microns	72 0	57 25	34 5	92 5
20-30 microns	17 25	30 0	50 75	4.25
30-40 microns	4 5	5 75	7 75	1 00
40-50 microns	4 0	3 50	3 00	
50-60 microns	1 25	0 50	3 50	0 25
Average microns	19 1	20 3	23 9	14 7

Properties of Specialty Hair Fibers

Physical properties The fleeces of the llama and the alpaca are similar in character to Angora goat hair During the years of breeding, the undercoat has disappeared and the hairs have become quite uniform in diameter and length A high percentage of kemp is present in the llama, whereas the fine alpaca has practicully none The raw fiber contains a small amount of natural grease (less than 4 per cent), and the total amount of impurities does not exceed 25 per cent The average yield of fiber is 80 per cent. The length varies from 4 to 11 in as shown in Fig. 20 in the length curves of the main specialty hair fibers.

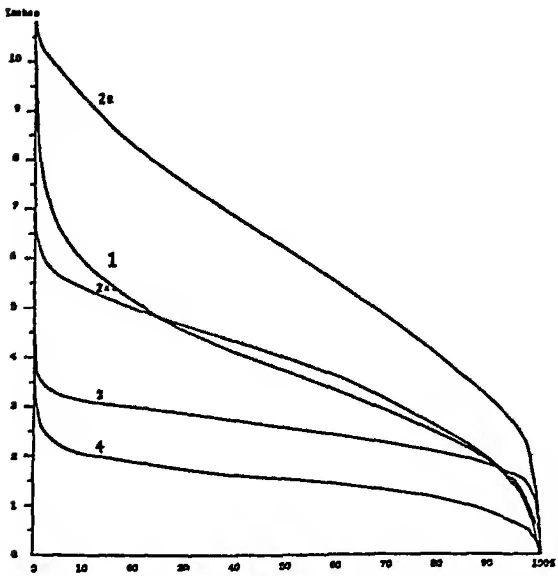


Fig 20 Comparative length of Alpaca, Kid mohair, Camel hair and Cashmere tops (1) Alpaca top (2-A) Kid mohair 6 month top (3) Camel hair top (4) Cashmere top (2B) Kid mohair 12 month top

Alpaca (1) and six-month kid mohair (2*a*) tops show the same average length, 3 8 inches, but the alpaca is far less uniform, which is indicated by the difference in the coefficient of variation alpaca 42 per cent and mohair 34 per cent The sample of twelve month kid mohair top (2*b*) has an average length of 6 1 inches, with a coefficient of variation of 38 per cent The average length of a fine camel's-hair top (3) is 2 1 in against 1 5 in of a cashmere top (4), with a coefficient variation of 24 per cent of camel's hair and 33 per cent for cashmere

The vicuña fleece has two distinct types of hairs, similar to camel hair the outer or beard hair and the under or wool hair Beard

hair is not used, whereas the wool hair, which grows close to the skin, is the softest and finest wool fiber used in wool manufacturing The average length is about 2 inches

Strength The figures given in the literature regarding the strength of these specialty hair fibers vary considerably. Table 17 shows results, establishing the strength factor on a more scientific basis, obtained in the laboratory of the Forstmann Woolen Company.

TABLE 17

BREAKING STRENGTH OF SPECIALTY HAIR FIBERS
(Standard conditions. 70° F. at 65 per cent R.H ; bundle test on tops)

Quality	*Average Fineness (microns)*	*Average Bundle Size (grams)*	*Average Breaking Strength* (lb. per sq. in)*	*Coefficient of Variation (per cent)*
Mohair, super kid	25 4	0 0889	35,610	2 4
Mohair, 32s	30.0	0.0896	35,220	1 1
Mohair, 22s	36.4	0.0891	35,330	2 5
Cashmere down	15 0	0.0296	23,870	3.3
Camel's hair, fine	20 7	0.0578	29,590	3 2
Camel's hair, coarse	26 6	0 0603	29,880	3 2
Alpaca, white	27.0	0 0944	30,090	0 7
Alpaca, light brown	27 0	0.0885	28,870	2 6
Alpaca, black	27 0	0 0915	27,810	3.4

*Calculated on a dry basis

Note· Length of the test specimen· camel's hair, 2 in., mohair and alpaca, 3 in., cashmere, 1 in.

The specialty hair fibers were found to be generally stronger than the wool of the same fineness, with the mohair fibers leading in strength. It is interesting to note that the fineness does not influence the strength, as it does in wool The amount of dye pigments present has a clear influence on the alpaca fiber, with the black alpaca approximately 8 per cent weaker than the white. The fineness of the various hairs yielded by the members of the llama family is indicated in Table 18

Expressed in wool fineness terms, llama, alpaca, and huarizo range between a 56s and a 60s wool grade, with the baby llama as

fine as 70s The vicuña is between a 120s and a 130s wool quality, which indicates that the vicuña is by far the finest fiber of all wools and specialty fibers.

TABLE 18

FINENESS OF COMMERCIAL HAIRS FROM LLAMA, ALPACA, AND VICUÑA

Types	*Llama* Raw Mixed	*Llama* Baby Scoured	*Alpaca* Scoured Piebald	*Alpaca* Tops Various	*Huarizo* Scoured Carded	*Vicuña* Scoured Carded
Number of fibers measured	500	400	1000	1200	500	1100
Average *	27 0	20 1	26 7	27 3	25 8	13 2
Standard deviation *	6.3	4 4	7 1	8 0	6 1	2 3
Standard error *	0 28	0 22	0 22	0 23	0 27	0 07
Coefficient of variation, per cent	23 3	21 9	26 6	29 3	23 6	17 4
Dispersion *	10 to 60	10 to 40	10 to 60	10 to 60	10 to 50	6 to 25

* In microns

Microscopical characteristics The epidermal scales of all hairs of the llama family are very indistinct, although present, similar to camel's hair The cortex is regularly striated and filled with color pigment except in the white The main characteristic is the presence of interrupted medulla In general, less than 10 per cent of the fibers are nonmedullated In the beard hairs, this medulla shows a contraction in the middle, appearing as a double channel, as seen in the cross section of the alpaca hair This form of medulla is of great aid in fiber identification (see Figs 21 and 22)

Chemical properties Harris found a sulfur content of 4 17 per cent and nitrogen content of 16 3 per cent in an alpaca sample In vicuña hairs the sulfur content was 4 1 per cent and the nitrogen content 16 26 Compared with wool and other specialty hair fibers, the sulfur content is approximately 0 5 per cent higher In general behavior toward chemicals, they are similar to mohair and camel's hair, and show poor fulling properties

From time immemorial the fleeces of the llamas have been used by the Indians in the production of blankets and rugs In England the world-famed village of Saltaire, Yorkshire, was developed by Sir Titus Salt, following his discovery of the use of alpaca for ladies' dress fabrics In the United States the alpaca, llama, and vicuña fibers have been extensively employed for women's apparel and men's coats by mills such as Forstmann Woolen Company, S Stroock & Company, Worumbo Mills, and others Owing to the beautiful colors of these fibers they are employed to the best advantage in their natural colors or mixtures of the same

Alpaca white hair (Longitudinal) (X240) — Fawn and white (Cross section) (X500)

Fig 21

(Longitudinal) (X240) — (Cross section) (X500)

Fig 22 Vicuña

Imports and Prices

Table 20, covering imports of the various specialty fibers, indicates clearly the growing use of these fibers in the United States

TABLE 20—IMPORTS INTO THE UNITED STATES
(In thousands of pounds)

Calendar Years-Av.	Mohair	Camel Hair Free*	Camel Hair Dutiable	Camel Hair Total	Alpaca, etc †	Total
1931–35	302	35	102	137	474	913
1936–40	403	51	239	290	1,994	2,687
1941	734	124	480	604	3,688	5,026
1942	690	38	66	104	3,814	4,608
1943	789	3	87	90	4,809	5,688
1944	6,673	6	96	102	4,628	11,403

* Under the Tariff Act of 1930 camel's hair may be imported duty free for manufacture into press cloth, camel's hair belting, rugs, carpets, or any other floor covering, knit or felt boots, or heavy fulled lumbermen's socks
† Includes the hair of the cashmere goat
Source National Association of Wool Manufacturers, *Bulletin*, 1945

During World War II the American government established the ceiling prices given in Table 21 for the various specialty hair fibers, per pound

TABLE 21—U S CEILING PRICES OF SPECIALTY HAIRS
(Per pound)

Wool 64s	Kid Mohair Matchings 32s to 40s	Cashmere Wool	Cashmere Noils	Camel Hair Fleece	Camel Hair Noils	Alpaca Dark and White
$1 18	$0 90 to $1 25	$1 40	$3 00 to $5 00	$1 25	$2 50 to $3 00	$0 65 to $1 25

Cow Hair

Cow hair is extensively employed as a low-grade fiber for the manufacture of coarse carpet yarns, blankets, and felts It is seldom used alone, always in mixtures with wool on account of its short staple The world is principally supplied by Siberia In the United States domestic cow hair is obtained from the skin of the slaughtered animals by a pulling process The coat of the cow is com-

posed partly of hairs without medulla and partly of fine and coarse beard hairs strongly medullated. The fibers occur in a variety of colors, including white, brown, black, red, etc. The length varies from less than ½ inch up to 2 inches. The diameter of the hair varies in wide limits from 12 to 180 microns Commercial samples as used in the carpet trade show an average of 36 microns

The main microscopical characteristic is that the scales are so finely toothed and arranged that there are about twelve in 100 microns The cortical layer is finely striated and the medulla is single-rowed with narrow distinctly outlined cells, filled with air.

Because the amount of cow hair produced in the United States is not enough to meet the demand, large quantities have had to be imported, mainly from Canada, Japan, Germany, England, and Spain

The average imports of cattle hair in the five-year period 1931-1935 amounted to:

	Pounds
Body hair at $0 05 per pound	3,127,000
Long tail hair at $0 14 per pound	3,190,000
Total	6,317,000

Source U S Tariff Commission, Comparative Statistics, Vol V, Pt 3, *Wool and Hair*

Horse Hair

Horse hair finds little use in ordinary woolen and worsted goods The mane and the tail hair are used in manufacturing upholstery cloth for railroad car seats, whereas the much shorter body hair is mainly used as stuffing for upholstery Horse hair is also used in men's suits and coats

In microscopical structure horse hair is similar to human hair In cross section, contrary to the human hair which is mostly elliptical, it is highly circular and strongly medullated The dispersion range is mane hair, 50 to 200 microns, and tail hair, 75 to 280 microns

The same conditions exist in the horse-hair market as in the cow-hair market United States production is not sufficient to meet the demand, therefore large quantities have to be imported, mainly from China, Argentina, Russia, and Canada. The average imports of horse hair in the five-year period 1931-1935 amounted to:

	Pounds
Tail and mane hair at $0 47	1,217,000
Raw horse hair at $0 12	1,593,000
Total	2,810,000

Source U S Tariff Commission, Comparative Statistics, Vol V, Pt. 3, *Wool and Hair*

Musk Ox

Musk ox wool is at present not a commercial fiber A small amount of wool, approximately 50 pounds, is produced by animals which are at present being domesticated in Alaska under the supervision of the Biological Survey of the Department of Agriculture. This hair is cut and spun and the yarn used for producing shawls, gloves, and socks by the pupils of Fairbanks College It is the hope that these rare animals may be successfully domesticated and their number increased to utilize part of the vast food reservation of Alaska, which is now largely wasted, and to afford a staple source of meat as well as valuable robes This hair may some day become one of the most important specialty hair fibers The musk ox looks somewhat like the small sized bison It is similar to both the sheep and the buffalo, probably resembling most closely the American bison There are four known species of the animal The animal which is at present being domesticated is the white-faced musk ox (*Ovibos moschatus wardi*) Its main characteristic is white spaces between horns and the face, the general color is dark gray The coat of the animal consists of an outer covering of coarse brown or black beard hairs which are very long and conceal the upper half of the legs Next to the skin is a growth of very fine light gray wool It is the fineness of this down which makes Werner von Bergen believe that this animal will some day become an important producer of valuable textile fiber Musk-ox wool hair is comparable to cashmere wool

Fig 25 Four year old musk ox bull *Courtesy Bureau of Biological Survey, Alaska*

Angora and Other Rabbit Fibers

Recent years have seen the introduction in woolen and worsted manufacture of several fur fibers to produce novelty effects of a different nature than were known heretofore. Into this group comes the hair of the angora rabbit, the hair of the various species of the common rabbit, muskrat hairs, and beaver hair Of these, the hair of the Angora rabbit is the fur fiber that has been longest used in the textile industry.

Angora rabbit hair. The wool of the Angora rabbit has been spun by French country women for more than a hundred years Today there are in France some half dozen small factories spinning Angora wool yarn. The animal is raised mostly by peasant women living in provincial towns, and only a few breeding farms specializing in Angora rabbit exist. The production of the two main countries in 1929 was. France, 130,000 pounds; England, 16,000 pounds To some extent the Netherlands and Belgium have also had a part in Angora-rabbit-hair production.

The importation of Angora rabbit wool from France at $5 00 and more per pound has stimulated the domestic breeding of this animal The total amount grown in the United States in 1947 was estimated to be around 120,000 pounds The United States Department of Agriculture gives the following advice to breeders.

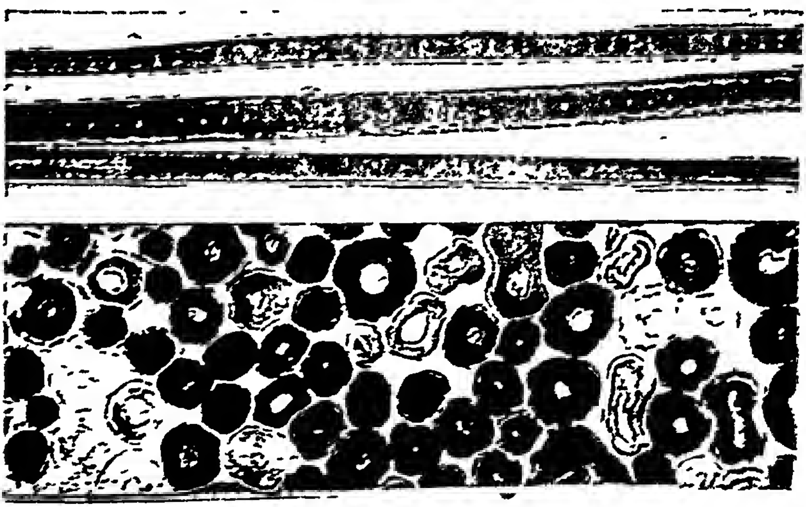
The Angora rabbit is too small for practical use in meat production (its weight at maturity is only 6 pounds), and its skin has little value in the fur trade, but as it produces a wool that is an article of commerce, Angora raising, if conducted carefully and conservatively. has a proper place in agricultural production It is not a get-rich-quick enterprise; fortunes such as those promised by some promoters will not be realized from it In Colorado, the center for Angora raising in the United States, an association formed by the breeders for the marketing of the hair has set up standards for six grades, as given in Table 22.

Breeding. Properly attended, an Angora rabbit will yield 10 to 16 ounces of hair per year. The wool, which grows in a year to a length of 5 to 6 inches, or in three months to a length of 2½ to 3½ inches is usually clipped four times a year. The weight of each clipping varies from 2 to 3 ounces. The greatest quantity of wool is produced in winter. At this season ¼ inch should be left unclipped to protect the rabbit against cold.

TABLE 22—COLORADO GRADES OF ANGORA RABBIT FUR

Grade	Appearance	Length (inches)
1	White, free of mats, stains, foreign matter	2¼—3
2	White, free of mats, stains, foreign matter	1¼—2
3	White, free of mats, stains, foreign matter	1 —1½
Shorts	White, free of mats stains, foreign matter	½— ¾
4	White, clean mats, large or small	various
5	Soiled and stained	various

Microscopical characteristics The hair consists of two kinds, a very fine wool hair and the coarse beard hair, or guard hair, as it is called in the fur trade The main characteristic of both types is the presence of a discontinued medulla in all hairs The medulla is formed by rectangular cells arranged in a manner of a string of pearls.



Top. Longitudinal (X240) Bottom· Cross section (X500)
Fig 26 Angora rabbit hairs

1. Wool hair. The wool hair shows only one row of medulla cells The medulla is not present in the tip of the fibers and also not in the root part of the fiber. The epidermal scales are very close together and in many instances the forward edges terminate in a sharp point.

As a whole the average fineness of the down hair is nearly equal

for all the grades. It varies from 12 to 14 microns with a dispersion range from 7 up to 30 microns.

2 Guard hair. The beard hair contains from two to eight rows of medulla cells, depending on the width of the hair, each varying from 30 up to 120 microns The cross section (Fig. 26) of the rabbit hair is very characteristic and offers the best method for identification of the fibers

Manufacture Because of its high cost and fluffy nature Angora rabbit hair is used mostly in conjunction with other fibers, like wool, spun silk, and, more recently, spun rayon and cotton. The percentages may vary in combination with wool from as low as 2 per cent up to 70 per cent for knitting yarns Years ago, the stiff white hairs were merely used to give frosted effects on the surface of the fabrics, which can be done with 5 to 10 per cent of rabbit hairs In using higher percentages, one of the biggest difficulties which confronts the millman is to prevent flying and the effect of static electricity, in order to make carding and spinning possible This can be accomplished either by pretreatment of the fibers with special oils or by careful lubrication during the blending process During the blending in the picker, all openings must be closed to eliminate losses In carding the licker-in and the doffer should be set close The yarn can be spun on both woolen and worsted systems

Effect yarn with rabbit hair is principally used as filling Twenty per cent to 25 per cent rabbit hair in the filling of a fabric will give it a very soft hand In dyeing the rabbit-hair mixture produces a two-tone effect, the rabbit hair dyeing lighter, because of the medulla present in the fibers and the high fineness

Common Rabbit Hairs

Because of their high price, Angora rabbit fibers are not used in other than luxury fabrics As a substitute, the much less expensive hair and fur by-products of the fur and hat industries, are used in the majority of so called rabbit hair fabrics Of these industries, the fur cutting industry, whose center in the United States is in Danbury, Conn, has become the most important supplier of rabbit hair. It is estimated that the total amount of fur cut in 1945 was 6,200,000 pounds and in 1946 was 7,000,000 pounds Although the bulk of this was consumed by the hat making industry, the textile industry, particularly the woolen industry, used approximately 425,000 pounds in 1945 and 500,000 pounds in 1946.

The type of rabbit hair most desired by the textile industry comes from the white, French type of rabbit It is obtained from France and other European countries as well as from North America, China and Japan The general trade term for this fur is "Coney" hair

In addition to this coney hair, there are various fibers obtained from hares, mostly supplied by central and eastern Europe and South America One of the best types of fur is obtained from the Russian hares known as zayats These pelts come chiefly from the regions of the Ob and Enisei Rivers in Siberia The cheaper grades of rabbit hair are obtained from gray, wild rabbits from Australia, New Zealand and Great Britain

Fur Cutting Operations

The pelts used in the fur cutting industry are graded according to the size of the skin and the richness of the underfur The grades for English rabbits are *best wilds, half wilds, first, second, third racks, suckers and mites*

The raw pelts in bales are preserved superficially by camphor or refrigeration When they are received by the fur cutting industry, they are hard, dry and tough and must undergo certain preparatory processes as follows

(a) *Opening* To make the pelts suitable for further handling, they are worked with water-dampened sawdust for 10 to 15 minutes in closed, rotating drums after which they are transferred to an open, caged drum for the removal of the sawdust The pelts are then given to workers, called openers, who slit them, and cut off the ears, paws and tails

The opened and trimmed pelts are again placed in closed drums with sawdust, Fuller's earth and other cleansing materials whose function is to remove grease and dirt which clings to the fur, thereafter they are again transferred to the open, caged drums for the removal of the cleansing agents and foreign matter

(b) *Stretching* Some pelts, especially English rabbit skins, which have a thick hide, have a tendency to wrinkle during drumming, the previously outlined cleaning process Such skins are put through a stretcher, a machine which flattens the skins between two rollers

(c) *Plucking and/or Clipping* The pelts treated as described above are now ready for the removal of the guard hair, which is undesirable because of its lack of felting ability This hair is pulled from the skin by a machine called a plucker Much good underfur is also lost in this process along with the *plucking,* the name given to the guard hair pulled from the skin Then too, it is a highly time consuming operation. For

this reason only pelts whose fur is to be used for high quality hats are plucked Even after plucking, too much guard hair remains and it is necessary to remove a further portion of it by clipping, the process of shearing off the tips to reduce the fiber to the desired length. The skins are clipped high, medium or low, depending upon the quality desired Except for the highest quality fur, the skins usually undergo only the clipping process, which removes sufficient guard hair for most purposes The lowest grades of skins, which contain too large a proportion of guard hair, are neither plucked nor clipped and the resulting low quality fur is designated as *unpulled*

The next operation for fur intended for hat manufacture is *carroting* This process consists of application to the fur on the skin of a chemical solution which is a mixture of strong acids such as nitric and sulfuric as a hydrolyzer, combined with hydrogen peroxide or potassium permangante as an oxidizing agent The purpose of this treatment is to enhance the felting properties of the fur This carroting process is not used on fibers supplied to the textile industry

Cutting

The unpulled or clipped pelts are then ready for the cutting process The cutting machine by which the fur is separated from the skin consists of a stationary bed knife and a revolving cylinder having four long knives fitted at an angle to the longitudinal axis, much like a lawn mower Feed rollers bring the skins between the bed knife and cylinder knives cutting the hide into small shreds and dropping them to the rear of the machine The fur falls in the form of a fleece onto a moving, endless apron which transports it along the fleecing table where workers, called fleecers, pick out by hand both machine pieces (pieces of skin, mostly with fur, which passes through) and greasy fur (lumps of fibers held together by grease or dirt)

Blending

The cut fleeces are collected in boxes or baskets to be transported to the mixer for blending the fibers from the various skins The machines are similar to the wool mixer, consisting of large, rotating cylinders with steel teeth, known as separators because, in addition to the mixing, skin pieces and lumps of fibers still sticking together are separated from the fur itself

From the separator the fur is transported to a mixing picker, a machine similar to the separator but rotating at a higher speed From the delivery end the stock, instead of being dropped to the floor, is blown into a receiving bin, wherein the fur fibers are suspended in the air for a considerable time, resulting in more thorough mixing The

mixture is then ready for the blowing process which has as its object a further elimination of undesirable guard hairs as well as dirt particles still present in the blend.

The blowing machine consists of from three to eight sections each of which is an enclosed cabinet connected with adjacent ones by feed rollers In addition to the pair of feed rollers, each section is provided with a fine-wire-mesh drum and a picker, which is a roller with thousands of fine steel teeth The picker combs the fur and throws it onto the revolving drum, the speed of rotation throws the fur up, and the desirable, specifically lighter underfur travels to the next section while the dirt and the specifically heavier guard hairs drop to the bottom. The fur travels in this manner from section to section, being cleansed and dehaired in the process According to the quality of fur desired, i e, lower or higher amounts of guard hair, the blowing may be repeated several times The blown fur is then packed in paper bags in quantities of five pounds and supplied to the textile manufacturer in cases comprised of 300 pounds of fur in sixty paper bags containing five pounds each

The cheapest quality fur is boiled fur This fur is obtained from the tails, ears, snouts and paws of the raw skins by boiling them in 3 per cent sulfuric acid solution Pieces of dressed skins obtained from the fur factories as waste are handled similarly This fur is washed and dried, then blown Boiled fur can be recognized microscopically by the presence of cracked and shattered fibers Also due to the presence of strong acid, the pH is generally quite low (2-3).

The average fineness of coney hair and other common rabbit hair is from 13 to 15 microns The length is usually less than ¾ of an inch and the presence of guard hairs varies according to the blend

Muskrat and Other Fur Fibers

Other types of furs occasionally used by the textile industry are muskrat, beaver, nutria, fox, wolf, mink and skunk Previous to World War II the use of muskrat fur in woolens was introduced by a few woolen manufacturers as a specialty, using the guard hairs to produce a glittering effect similar to that of tussah silk The popularity of fabrics containing this type of fiber was very short lived During the short period in which they were used, the price of muskrat guard hair climbed from a few cents to $7 00 per pound

Price—The cost of preparing fur fibers is usually absorbed entirely in the costs of the production of which the fibers are a by-product.

The market price depends on the available supply at the time of the demand The exceptions are Angora rabbit hair and the fibers obtained from Russian hare, which are processed for textile purposes only The prices, therefore, vary over a wide range In spring 1947, the following prices were quoted in the New York market

TABLE 23—PRICES OF RABBIT HAIRS PER POUND

French Angora	$9 00
White Russian	7 50
White Domestic Fur	5 50
Arctic Hare Fur	4 00
Cheap Grey Rabbit Hair	2 50
Plain White Spike Rabbit	1 50
Gray Fur Rabbit	1 40

The chief market in the United States for the trading of pieces and some of the cut furs is New York The cut and blown fur is obtained from cutting plants in Danbury, Bethel and South Norwalk, Conn Other plants are located in Philadelphia, Penna , and Newark as well as Paterson, N. J

Feathers

One of the most peculiar effects of recent origin is produced by an admixture of feathers with wool. All kinds of down from genuine ostrich to goose and duck feathers are used The biggest supply is found in goose down, generally used in the stuffing of pillows Even the quills are now being used by cutting up the down. The normal percentage in mixing is about 20 per cent, which produces a handle that cannot be otherwise obtained The feathers used are very short—never longer than five-eighths of an inch—and they have been found to blend very well with a carded woolen yarn The feathers stand on the surface of the yarn without being too loose and when woven into the cloth they still remain on the surface. For piece dye effects the mixtures may be spun in all white. For more exclusive fabrics, colored wool with various percentages of white down may be used. A two-tone effect is produced by piece dyeing because the feathers dye lighter than wool.

A novel feature of such cloths is that the slightest movement of the cloth in a current of air causes a faint ripple of the protruding down The softness of the down content is enhanced by the use of a fine-quality wool

Chapter 6

RECLAIMED WOOL AND SECONDARY RAW MATERIALS

THERE are two primary reasons why manufacturers of wool fabrics and other wool clothing products find it necessary to utilize re-used or re-worked wools, vegetable and other substitute fibers in making wool materials Primarily, the world's wool supply is insufficient to meet all industrial and clothing requirements for wool and secondarily, the use of all virgin wool would make the materials prohibitively expensive By far the largest percentage of wool clothing needs falls in the inexpensive price class and to produce these materials fibers other than new wool must be used Fibers such as silk, cotton, or linen are combined with wool to give additional strength and to produce special effects Rayon, particularly in the form of staple fiber, rapidly is becoming one of the most important secondary raw materials in the woolen industry While it is often described as an alternative material, actually it is a diluent or cheapening element

Table 1 clearly shows the shift in importance of the various additive

TABLE 1 RAW MATERIALS CONSUMED BY THE WOOLEN AND WORSTED INDUSTRIES IN 1929, 1939, 1945 AND 1946

(Million pounds)

Raw Material	1929	1939	1945	1946
Shorn and pulled wools	354	296	516	529
Recovered fibers	93	118*	161*	168*
Cotton and cotton waste	20	15	42	39
Rayon staple and waste	4	16	36	44
Noils	51*	26	31	39
Mohair and mohair waste	24	21	13	20
Other specialty hairs and their waste	10	7	6	6
Silk	2	1	—	—
Other fibers	—	3	4	5
Totals	558	503	809	850

* Included in the 1929 noil figure is the mill waste In 1939, 1945 and 1946, the mill waste is included with the recovered fibers *Source Bureau of Census*

raw materials used in the woolen and worsted industries in the United States from 1929 through 1946

MANUFACTURING WASTES

It is common practice for a manufacturer to reuse, to as great an extent as possible, the unavoidable waste occurring during the various processes. Most of this waste is in such a form that it can be re-embodied in the regular lots. Such manufacturing wastes are generally grouped into four classes.

1. Noils
2. Soft wastes
3. Hard wastes.
4. Finishing wastes

Noils. These are the short fibers separated from the long wool in the combing process. Because the treatment they have received is not detrimental in any way, they are equal in quality to virgin wool except for their length. They constitute one of the main raw materials in the production of woolen goods and are handled as a regular commodity by wool dealers. Noils and the wool from which they were combed are classed under the same quality number. For example, a 60's wool produces both 60's top and a 60's noil. Actually, noils were found by microscopic measurements to be normally one to two grades finer than the wool from which they were combed, because the short fibers in a staple are slightly finer. This fineness relationship in carded wool, wool top and noil was studied by the Agricultural Marketing Administration, in cooperation with nine industrial laboratories. Their results, comprising more than 90,000 measurements made according to A.S.T.M. standard procedures are given in Table 2.

TABLE 2. AVERAGE FINENESS OF TOP, SLIVER, AND NOIL COMPARED WITH WOOL TOP STANDARD FINENESS RANGES

Grade	*Fineness Range Wool Top Standards Microns*	*Average Fineness of Test Lots* — *Top* *Microns*	*Top Grade*	*Card Sliver Microns*	*Card Sliver Grade*	*Noils Microns*	*Noils Grade*
70s	19.6 to 21.0		.			...	
64s	21.1 to 22.5	21.3	64s	20.8	70s	19.6	70s
62s	22.6 to 24.0		...	...	..	.....	......
60s	24.1 to 25.5	24.0	62s	23.5	62s	21.4	64s
58s	25.6 to 27.0	26.0	58s	25.1	60s	22.8	62s
56s	27.1 to 29.0	27.5	56s	26.9	58s	24.3	60s
50s	29.1 to 31.5	30.4	50s	29.4	50s	26.0	58s

For marketing purposes, six classes of noils are produced (1) Bradford, (2) French, (3) prepared, (4) hair, (5) colored, (6) carbonized Bradford or English noils are obtained from the Noble or Holden comb French noils are derived from the rectilinear or French comb Both types are combed from fine and medium wools Bradford noils are the more valuable because of their greater length and lower vegetable matter content The fine quality noils have a high nep content, clusters of knotted and entangled fibers produced partially in the scouring process, but mainly during carding In buying noils stress is laid on the grade, length, strength, vegetable matter content and color The market value depends on the demand and at times exceeds the price of the original wool In grades they range from 80s down to 50s quality

Prepared noils consist of coarse cross-bred and long wool fibers whose qualities range from 36s to 50s They are free from neps since they have not been carded, but the short fibers are in batches or slubs

Hair noils are derived from combing mohair, camel hair, alpaca and cashmere Camel hair and cashmere noils are by far more valuable than the top because they contain the fine down

Colored noils When top is dyed in the form of slubbings or in packages, re-combing is often necessary to put the slivers back in suitable form by separating and straightening out the partly entangled and felted fibers This re-combing operation produces the colored noils, which are much shorter than the white noils but nearly free of neps

Carbonized noils. Since the comb not only removes the short from the long fiber, but also extracts vegetable matter such as burrs and straw, the resulting product is a mixture of both To improve the value of the noils, they are in many instances subjected to a carbonizing process (see Chapter 9) which destroys the vegetable matter. In addition to the vegetable matter, noils contain tar or other insoluble materials used in sheep branding. The removal of this branding substance is accomplished by a depitching process. Depitched and carbonized noils are particularly valuable in the manufacture of white woolen flannels and similar fabrics

Soft waste is a product of woolen and worsted carding, combing and drawing and is classified as *card waste*, *combing waste*, *roving waste* and *laps* (soft waste from worsted drawing and spinning). The main characteristic is that the material is still in a fibrous condition and, therefore, in most instances these wastes are blended with virgin wools before carding. Card-stripping, combing wastes fly and floor wastes

must undergo dusting and opening treatments. Straight colors and mixed blends of course, have to be kept separate The woolen spinner is the main user of soft waste

Hard waste. The waste occurring after the spinning operations contains twist, and is no longer in a fibrous form. For these reasons it is known as *hard* waste. This kind of waste occurs in spinning, twisting, respooling, winding, warping and weaving To utilize this waste in blends requires careful sorting, followed by an opening process In sorting, these wastes are classified as *colored, white, hard twist, soft twist* and *mixtures* of twists or related yarns After sorting, they are put through a picking and garnetting process. The operation of picking serves to tear the yarns apart into shorter lengths which, during garnetting, are reduced to a fibrous condition Small pieces such as head-ends from the weave room are also included in the hard wastes and treated accordingly Returned to a fibrous condition, the fibers, of course, are reduced in length, and consequently in value, yet they form a valuable raw material for the woolen spinner

Sweepings from the spinning and weaving rooms contain much usable material, such as short pieces of roving and yarn After screening and sorting, a scouring and opening process follows, if required

Finishing wastes Cloth finishing produces three types of waste (a) flocks from scouring and fulling, (b) shear flocks, (c) short ends and sample wastes.

Flocks resulting from piece scouring, fulling and raising are of a low grade because of uneven length and their mixed and soiled condition *Shear flocks* are obtained from cropping or shearing piece goods and constitute a valuable raw material for pressed felts, packing of bedding and wall papers They are more even in length and generally cleaner than the flocks from scouring and fulling, but may contain up to 5 per cent lubricating oils picked up during the shearing process. They are employed in fulling low grade woolens to give additional weight by felting the short fibers into the tacked goods

Short ends and *sample* wastes, together with new tailor clippings, are the main source of reprocessed wool

The large woolen mills operating both systems of spinning offer to waste dealers only the various wastes unsuitable for their own use The waste dealer takes care of the sorting, picking and garnetting, makes up special blends and resells them to manufacturers of cheap woolen goods. Wastes from mixed materials, wool and cotton, wool and rayon, etc, are sold by the dealer to reworkers, which in turn extract the wool from them

RECOVERED WOOLS

These materials are produced by woolen manufacturers, who may be independent enterprises or a part of woolen mills Table 1 shows that 118 million pounds of these materials, approximately 25% of the total fiber consumption, were consumed in 1939 by American mills In 1945, according to figures of the U S Tariff Commission, the amount increased to 161 million pounds or 20 per cent of the total consumption of the industry Recovered wool is used almost entirely for lower grades of woolen goods, and practically not at all in worsteds

The sources of recovered wools are clippings, new and old woolen and worsted rags, and other wastes from garment manufacture The rag man in any community collects the rags and disposes of them to local dealers, who classify them roughly according to the materials of which they are composed The rag merchants purchase them from the dealers who re-sort them in bulk by qualities, in which condition the rags are offered directly to the reworked wool manufacturers or to mills

METHOD OF RECOVERY

The first process which the rags undergo is sorting, during which the rags are separated into clippings, new rags, worn rags, pure wool, mixture of fibers, knitted fabric, woven fabric, fulled fabric, unfulled fabric, and the different colors

The bales of rags are opened and hand-fulls picked up and spread on a sorting table The operation is not particularly arduous but requires a knowledge of the various kinds of materials in order that they may be sorted in accordance with the above classifications For these reasons women are usually employed to sort rags

After sorting, the buttons, hooks, iron, and trimmings are removed, as well as the seam bits, which may contain cotton, rayon, or other vegetable fibers The latter are grouped in a class by themselves for later removal of vegetable fibers by carbonization

Before the actual tearing-up-process the rags may be run through a shaker to remove the surface dirt and dust, and to soften their texture With very dusty rags this dusting may be done even before sorting The shaker consists of a feed and delivery, a traveling lattice placed in front of the machine, and a large spiked drum, which rotates at a speed of 300 to 450 rpm A large fan carries off the dust

After these pretreatments, the rags are oiled to facilitate the grinding or tearing up process They are spread in layers and sprinkled with approximately 10 per cent hot oil in the form of a cheap mineral oil

emulsion. The oiled stock is allowed to lie for at least twelve hours to permit penetration of the oil The oiled pile is then divided vertically to secure an even distribution of the sorted rags and placed on the lattice feed apron of the rag picker illustrated in Fig 1

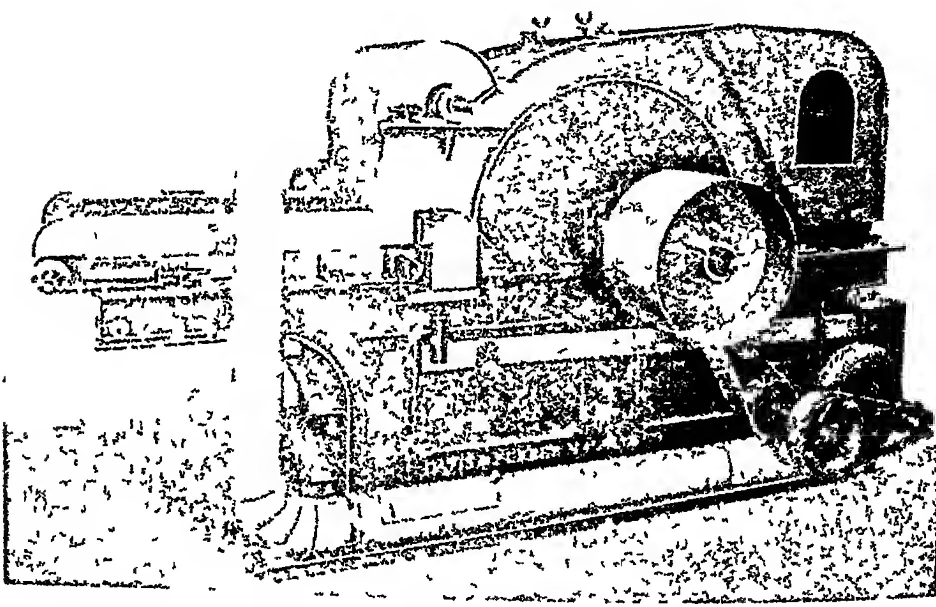


Fig 1 Rag picker *Courtesy Davis and Furber Machine Co*

The feed tables carry the rags to strong, fluted rollers, which feed the material to a cylinder provided with flat or rounded teeth or spikes There may be 52 teeth in a row for very hard goods and 28 teeth per row for soft goods on a width of 36 inches The production, which depends on the nature of the rags, may run from 500 to 750 pounds per ten-hour-day for mungo in a 36-inch-cylinder machine After the rags leave the fluted rollers, they are attacked by the teeth of the cylinder and separated into smaller pieces with the result that they are reduced to a partially fibrous condition Any oits of rags insufficiently torn come into contact with the blade of a special roller which automatically throws them back to the feed table to be re-entered into the machine.

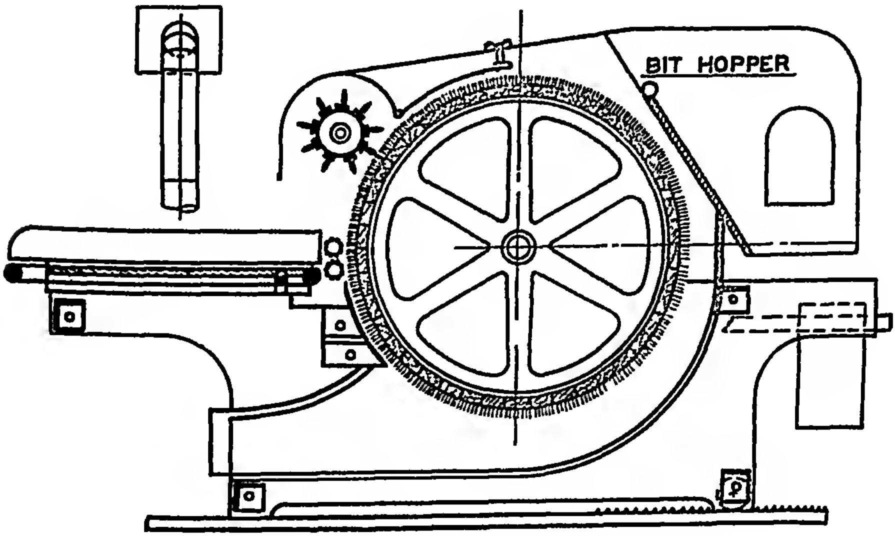


Fig 2 Sectional view of rag picker

Prior to carding the cloth must be subjected, in many instances, to a second process known as *garnetting*, to reduce it to a state sufficiently fibrous as not to be detrimental in the carding operation Compared with fleece wool the resultant material is deficient in fiber length and strength because of the broken, bruised and splintered fibers present The material in this fibrous form formerly was known as *shoddy*

The above procedure is the same, in general, for all classes of recovered wool However, certain differences do exist between the main divisions

The term *shoddy* was used before the passing of the Wool Products Labeling Act specifically to designate the product which is derived from all wool cloths which had not been felted or which had been felted to only a slight degree, i e, serges, cheviots and other worsted cloths and knit goods such as scarfs, jerseys, stockings and similar wool products Today, the fibers recovered from new, all wool woven or felted cloth have to be designated as *reprocessed wool*, whereas the fibers recovered from unworn knit goods can be classified simply as *wool*. When the fibers are recovered from wool products which had been used in any way by the consumer, the fibers must be designated as *reused wool*

Recovered fibers of the first type consist of wool fibers which are one-half inch or longer. The best quality of reworked wool is such that it can be spun without blending into woolen yarns although, as a rule, it is mixed with fleece wools and other fibers The resulting grade of woolen yarns is used to produce a large variety of cheap woolen goods, such as boys clothing, ski suits, coatings and overcoatings The skill and experience of a woolen manufacturer determines how closely he can imitate a better quality fabric made of new fleece wool though using various reworked fibers.

Mungo is the term formerly applied to fibers from old and new rags which have been fulled considerably or are of a very firm structure such as uniform kerseys, velours and meltons It consists of very short fibers, less than one-half inch in length In reducing this heavy material to a fibrous condition a considerable amount of force is necessary and consequently strong pickers and auxiliary machinery are employed This process damages the fibers and the spinning and felting properties are greatly reduced. These fibers are used mainly in cheap woolen blends and are extensively employed for stuffing threads and backing of double cloths

Extract wool is obtained from woolen or worsted fabrics partially made of cotton, rayon or other vegetable fiber mixtures To secure the valuable wool content of such fabrics, the vegetable fibers are destroyed by a carbonizing process. The different types of cloth are treated separately to obtain the best results. Two methods of carbonizing are practiced.

1 The sulfuric acid method
2 The hydrochloric acid method.

The principle of the process and machinery for the sulfuric acid method are practically identical with those described in Chapter 9 The method consists of immersing the rags in sulfuric acid, hydro-extracting, baking, dusting and neutralizing In the hydrochloric acid method the rags are treated in the dry state with hydrochloric acid gas fumes. The apparatus for the latter process consists of a large drum revolving in an enclosed chamber and of heated retorts, in which the acid is generated. The liberated gas penetrates the goods or rags and destroys the vegetable matter by decomposition. In the latest machines as much as 500 to 700 pounds may be treated at one time. The whole process is automatic, the material is fed into the machine in trucks on rails and the hydrochloric acid supplied in fixed quantities when the apparatus is in operation The temperature is raised to 212 to 200 degrees F in the baking tube and maintained for several hours. The gas fumes escape through a chimney. Following this process the rags

are taken out, cooled and shaken by a duster or a centrifuge The rags are given an additional beating in a cage shaker, which eliminates the vegetable matter as dust Because the vapor is dry, neutralizing is unnecessary except in unusual cases The hydrochloric acid vapor process has in its favor that it is simpler, less expensive and preserves the softness and luster of the recovered wool fiber Some concerns in France and Belgium use ammonia vapor for neutralizing purposes After the shaking, the material proceeds to the rag grinder, where it is shredded into the fibrous condition in the manner described for reworked wool

Extract wool is obtainable in various grades It has scarcely any felting properties and is mainly used in blends with wool and wool substitutes in low grade woolens which are not, or only slightly, fulled

TABLE 3 O P A CEILING PRICES FOR MILL WASTE, CLIPPINGS AND RAGS 1942

Worsted Wastes—Maximum Prices
(Expressed in dollars per lb)
Grades—Fine and ½ Blood

	——100% Wool——		*80-90% Wool –Balance other fibers–*	
Classification	*White*	*Mixed Colored*	*White*	*Mixed Colored*
Drawing laps	1 25	95	965	725
Spinning & roving laps	1 15	88	885	67
Rings	1 10	80	845	605
Worsted spinning threads	92	55	70	405
Worsted weaving threads	84	47	635	34
Worsted soft knitting threads	97	60	74	445
Scoured or carbonized, dusted neutralized, worsted card or strips	90	65		
Carbonized, dusted, neutralized burrs and burred burrs	70	45		
Doffer waste	32	20		

Woolen Wastes
Grade—Fine

	70-80% Wool —Balance other fibers—		*Less than 50% Wool —Balance other fibers—*	
Classification	*White*	*Mixed colored & khaki*	*White*	*Mixed colored & khaki*
Woolen rovings	365	24	125	075
Woolen threads	34	165	115	045
Woolen card waste	24	14	075	035
Woolen strips	075	015	015	015
Napper flocks ...	115	025	025	015

TABLE 3 O P A CEILING PRICES, *Cont.*

Men's Wear

Classification (sorted to grades & color)	—Free of Cotton Warps— 100% Wool	80-90% Wool Balance other fibers	Less than 50% Wool Cotton wps
Mixed suitings			
White and worsted woolens	52	37	13
Suitings 75% worsteds 25% woolens	20	12	.02
Suitings 100% woolens	15	08	02
Shetlands & Tweeds (Free of Nubs)			
Pastel	30	20	.05
Navy blue	28	185	04
Mixed tweeds	19	11	.02

Women's Wear

Classifications (sorted to grades & color)	—Free of Cotton Warps— 100% Wool	80-90% Wool Balance other fibers	With Cotton wps Less 50% Wool Bal others
Worsted crepes			
Pastel	37	.255	075
Navy blue	24	.15	.03
Woolen plaids			
Mixed light	.21	13	.025
Boucles			
Tan	.37	255	075
Snow and ski suits			
Navy blue	12	055	015
Scarlet	25	16	035
Meltons			
Navy	10	04	015
Blanket clips			
Pastel	40	28	09
Mixed dark	20	12	02

Knitted Wool Clips

Sweater clips	100% Wool	70-90% Wool	Less than 25% Wool
White	80	.29	12
Mixed dark	46	29	06

Graded Rags

Mixed Fine Flannels and Chongas
(All solid colors free of cotton warps and silk noils)

Solid colors	.12

Worsted Serges with Chongas and Flannels
(Free of cotton warp & silk noils)

Black	08
White	36

TABLE 3 O P A CEILING PRICES, *Cont*

Tricotines	
(100% *Worsteds*) *Free of cotton warps, tinsel & silk*	
Solid colors	12
100% Knits	
(Free of linsey)	
Pastel light jersey (all pastel colors)	33
Fine white wool underwear	26
Half Wool Knits (to contain a minimum of 50% wool)	
White	14
Graded to color	085
Linsey Sweaters (to contain a minimum of 30% wool)	
Light hoods	055
Sorted solid colors	045
Maximum Prices for Old Wool Rags, Mixed Stock	
Rough light overcoats	03
Rough dark overcoats	02
Rough cheviots	025

The relative values of the various mill wastes, as well as clippings and rags are best illustrated by Table 3 showing O P A ceiling prices for 1942 which prevailed during World War II

RECLAIMED AND VIRGIN WOOL

Under the microscope, new or virgin wool generally exhibits a characteristic epidermis structure of variously formed scales This scale layer is the protective covering for the cortical layer, which consists of a fibrous mass of individual cells These very fine, spindle-like cells are responsible for the strength and elasticity of the healthy fiber

The wool fiber usually withstands the constant bending, strain and pressure exerted on it by ordinary wear but, under excessive wear, the outer layer suffers and the whole fiber starts to break down in a manner similar to that in which a branch or twig is broken apart Such damage is quite severe when wool fabrics are reconverted to fiber form by picking and garnetting, but is not extensive when yarns are reduced to a fibrous state In several cases, similar broken fibers were found in the instep and vamp of worn cloth shoes The photomicrograph of four fibers which were subected to repeated bending illustrates this mechanical damage (Fig 3) A characteristic damage is the tearing away of the fiber's protective covering and splintering of the fibrous cortical layer The three photomicrographs in Fig 4 illustrate some of the forms of torn and raveled ends which were found in reprocessed and reused wools They may be present in varying degrees, according to

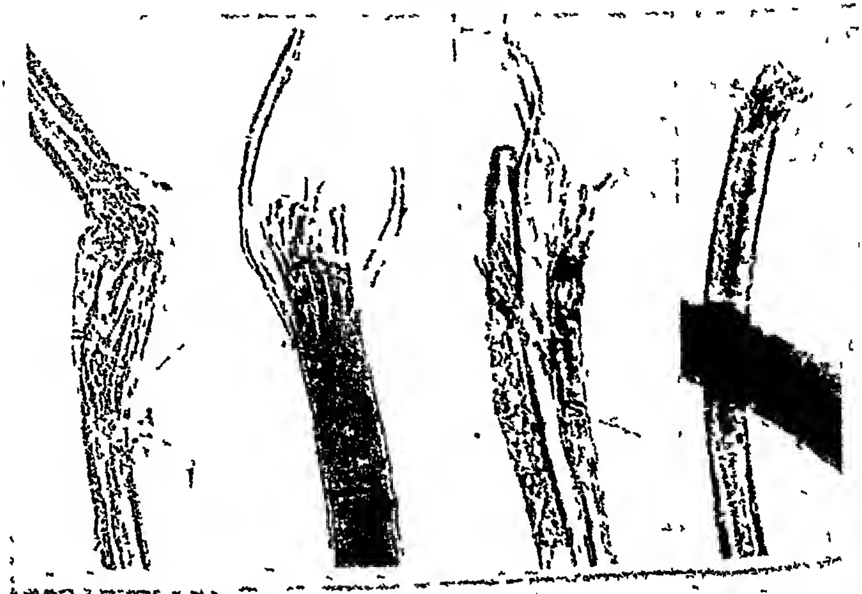


Fig 3 Four wool fibers damaged by bending and wear

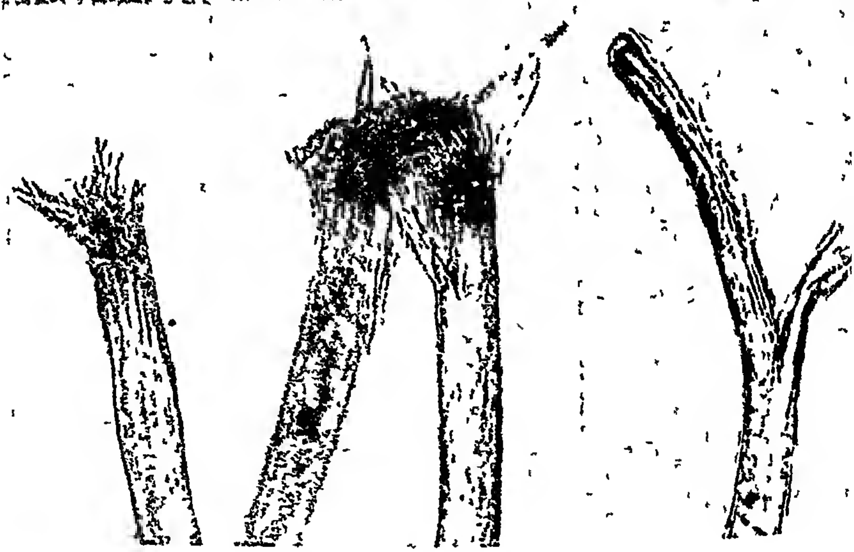


Fig 4 Three damaged wool fibers found in shoddy fabric.

the product from which they were recovered and the type of process necessary to reconvert them. The extent of the actual breakage and shortening of the fibers in manufacturing and reclaiming operations is illustrated by the comparative length curves of reclaimed fibers shown in Fig 5. The average length of fibers reclaimed from an undyed virgin

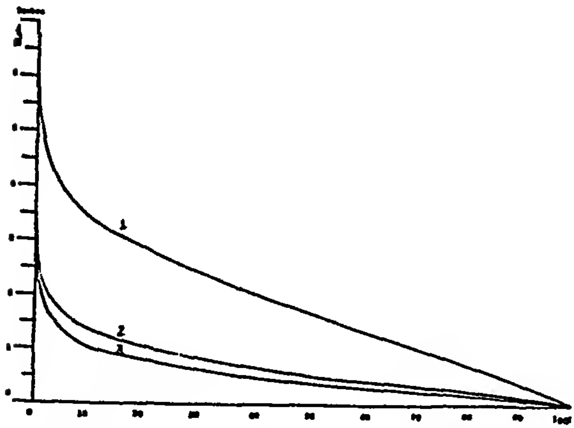


Fig 5

Comparative length of virgin against reclaimed wool

	Av Length	*Variation*
1 Virgin wool	1 9"	63 2%
2 Reclaimed (nat)	0 7"	71 4%
3 Reclaimed (dyed)	0 5"	80 8%

wool fabric in which new wool with an average length of 1 9 inches had been used was found to be 0 7 of an inch Naturally, part of this shortening was due to the original manufacturing processes but it is believed that the greater part was brought about by the reconverting process The average length of the fiber reclaimed from a similar dyed fabric was only 0 5 of an inch

The breaking strength, resistance to abrasion and elasticity of reworked fibers are lower than those of fibers which have not been through the manufacturing or reclaiming processes Comparative breaking strength and abrasion tests made on virgin wool and reprocessed wool fabrics of identical construction and finish gave the results shown in Table 4

TABLE 4 STRENGTH AND ABRASION RESISTANCE OF VIRGIN AND REPROCESSED WOOL FABRICS

	Virgin wool fabric		*Reprocessed wool fabric*	
	Original	*Redyed*	*Original*	*Redyed*
Breaking strength in lbs (ASTM grab test)				
Warp	31 1	30 6	9 8	6 6
Filling	31 3	29 9	9 7	7 3
Abrasion resistance in no of rubs (Wyzenbeek machine)				
Cloth against cloth	40,000		2600	2300
% damaged fibers	1 2		11 7	

If large numbers of badly damaged fibers find their way into a new piece of fabric, the resulting product is naturally inferior to one in which the fibers have been processed without sustaining such damage

One of the factors which makes it difficult, if not impossible, to

ascertain the exact amount of virgin wool and reclaimed wool in a finished sample is that a fabric which has been subjected to unduly vigorous manufacturing processes will contain a large number of damaged fibers even though it may be an original fabric made from the best fleece wool The chief sources of mechanical damage in manufacturing are in burr-picking, carding, combing, gigging, and napping operations, where there is danger of breaking down the fiber by improper setting of working parts, wrong quality of card clothing, and excessive raising.

The chief sources of chemical damage are 1) excessive alkali in washing and fulling, 2) prolonged boiling time in dyeing, 3) excessively strong acid in carbonizing and 4) excessively strong chemicals in bleaching In addition to this, baling wool in a moist condition may lead to severe bacterial damage as discussed in Chapter 4

Obviously, determination of the presence of reprocessed and reused fibers in wool fabrics, even with the most skillful microscopic methods, is very difficult As a rule, the manufacturer is the only authority as to whether or not reclaimed wool has been used in a specific cloth

While it is difficult to differentiate between virgin wool, wool, reprocessed and reused wool, the wool fiber content of fabrics can be determined qualitatively. To arrive at a just estimate, many comparisons must be made with known samples Research in this field indicates that the most important characteristic of reclaimed wool (reprocessed or reused) which may be considered in detecting its presence is the percentage of damaged fibers Results of studies made on fabrics containing various amounts of reprocessed wool compared with the same fabric constructions made of virgin wool are given in Table 5 Figures given are the average of at least three tests of 600 fibers each

TABLE 5 DAMAGED FIBERS FOUND IN DIFFERENT FABRICS
(in percent)

Fabric	*Velour Wool-dyed*	*Broadcloth Piece-dyed*	*Flannel Piece-dyed*	*Cheviot Piece-dyed*	*Cheviot Wool-dyed*
Original Blend	*½ blood Missouri*	*64's Penn Delaine 6 mo Texas*	*70's Ohio Delaine*	*⅜ blood Minnesota B/C S A Lamb*	*50% Domestic 50% Austr Lambs*
100% Virgin ..	2.04	1.27	1.79	1.54	1.39
50% Virgin, 50% Reprocessed	4.45	4.15	4.91	4.12	
30% Virgin, 70% Reprocessed				6.27	
100% Reprocessed	6.58	.	6.90		6.46

The number of damaged fibers in reused wool is higher than in reprocessed wool. This fact is substantiated by the results of the analysis of three samples shown in Table 6 From these figures it can be seen that blends containing 35 per cent reused wool and blends containing 100 per cent reprocessed wool have approximately the same number of damaged fibers.

The presence of fibers other than wool Today much wool is reclaimed from fabrics containing various amounts of cotton or, especially, of rayon fibers of different sizes, dull and lustrous To establish the percentage of different fibers present, a microscopic count of a fine cross-section is the preferred method, but a chemical analysis should also be made (See Fig 6)

Fig 6 Cross section of a shoddy yarn containing wool, rayon and cotton (*X 500*)

TABLE 6 DAMAGED FIBERS IN VARIOUS BLENDS

Sample	1	2	3
Blend	75% Wool 25% Reused wool	65% Wool 35% Reused wool	65% Wool 35% Reused wool
% damaged fiber	4 1	6 1	5 83

Variety in color of the fibers is characteristic of reclaimed wool, since the fabric sources cover a wide range of colors Though many of these fibers are redyed, the dye penetration is superficial and the original color of the individual fibers can be seen in fine cross-sections.

It is an interesting fact that of all Government fabrics, the 32-ounce overcoating of the United States Army is the only fabric in which the use of reprocessed and reused wool is allowed The specifications for this fabric state that the blends from which the yarn is spun shall contain not less than 55 percent sheep's wool, and not more than 35 per cent noils and/or reprocessed and/or reused wool Broken sliver from cards and mules made from the mixture of this fabric not exceeding 10%, may be added to the blend.

Except as provided above, the use of noils, card fly, card strippings, reused wool reprocessed wool, fiber obtained from sweater clips, garnetted hard ends and similar waste is not acceptable Government specifications allow a maximum residue of 2.5 per cent after caustic soda boiling

Chapter 1 under Labeling of Wool Products, gives the history of the approval of the Wool Products Labeling Act, in October, 1940 (See page 57.) This Act governs the labeling of the various mill wastes, clippings and rags in the United States, including all materials of a similar nature imported into this country.

SILK

Silk is the general term applied to the continuous protein filament secreted by various insects to form their cocoons. It commonly refers to the fiber from the cocoon produced by the larvae (the mulberry silk worm) of a bombycid moth (Bombyx mori).

In spinning the cocoon the worm secretes a viscous fluid, the fibroin, from two tube-like glands in its body. The two tubes fuse in a common exit in the head of the worm, into which a secretion, the sericin or silk gum flows from two other glands and cements the two fibroin filaments together. When it emerges from the spinneret in the head of the worm, the double fiber coagulates on contact with the air.

After the worm has finished spinning the cocoon and the larva has changed into the pupa or chrysalis, it is exposed to steam to kill the animal before its metamorphosis into the moth which would, by eating through the cocoon, break the filaments Unpierced cocoons yield from 400 to 700 yards of usable silk, which is unwound from the cocoons in silk-reeling establishments

In reeling cocoon filaments, four or more are doubled together to form the number of raw silk desired The silk number is expressed in denier The two main raw silk numbers produced in Japan are 13/15 denier and 20/22 denier. In 1939 the 13/15 denier raw silk amounted to 61 per cent and the 20/22 denier to 36 per cent of the total production.

Most of the raw silk received in the American market is rereeled into a standard skein 58 to 59 inches in circumference, weighing 2 4 ounces About 30 of these skeins are formed into bundles called *books* weighing about 4 5 pounds A bale, which is the unit size package for shipment, consists of about 30 books The average weight of the Japanese bale is 135 pounds, whereas the Cantonese bales weigh around 100 pounds

The chief silk-producing countries are Japan, China, Italy and France. Before the last war Japan produced approximately 80 per cent of the world's output, China 10 per cent and the remaining 10 per cent was produced by Italy and other countries, including France, Spain, North Africa, Turkey and India

The raw silk as received from the primary market is converted by a throwster into various silk yarns such as tram, organzine, georgette, sewing silk and embroidery silk required in the weaving or knitting of various types of fabrics

Microscopic structure When raw silk is examined microscopically, the fibers appear in bundles of eight, ten or more filaments, since four or more double filaments are reeled together. The individual strands composing the fiber are easily recognized, as the two filaments from each worm are normally joined together and enveloped by the silk glue

When raw silk is boiled in a soap solution, the gum or sericin, amounting to 18-23 per cent of the total fiber weight, is removed and the dual nature of the filaments is disclosed The degummed silk fiber is a smooth, structureless, translucent filament with occasional constrictions as well as swellings or lumps A concentrated acid, such as sulfuric, separates the fiber longitudinally into very fine filaments before it dissolves

Fineness The width variations of individual filaments, as measured on commercial samples, are shown in Table 7

TABLE 7 SILK FIBER WIDTH MEASUREMENTS

Origin	*No of Fibers*	*Average Microns*	*Per Cent Variation*	*Dispersion*
Canton	200	10 80	19 5	5-18
China Tram	200	11 75	24 0	3-21
Japanese Organzine	300	12 75	28 2	3-23
Tussah (China)	300	28 48	27 6	9-51

The characteristic cross-sectional shape of silk fibers offers the best method for their proper identification The silk fiber cross-sections are elliptical or triangular in shape, with rounded corners In raw silks the

two joined filaments normally face each other with the flat sides of the triangles in opposition Fig 7 illustrates four fiber bundles of eight filaments each in cross-section

Fig 7 Cross section of raw silk (X 500).

Spun silk. Raw materials for the making of spun silk yarns are the various types of waste silk. In silk manufacturing there are two major types of waste.

(a). Gum waste, produced at the primary source in rearing the silkworms or reeling the raw silk thread

(b). Throwster's waste, produced during the winding, twisting, warping and quilling processes used in converting the raw silk thread into yarns for weaving and knitting

The various raw wastes are first subjected to an opening process and then processed in much the same way as wool in the worsted system They are degummed (washed), combed, drawn and spun During the latter operation, wastes are produced similar to the silk noils from combing.

The combed fibers are usually classified in four grades.

1st Quality, 3 to 10 in fiber length, average 6 5 in
2nd Quality, 2 5 to 6 in. fiber length, average 4.5 in
3rd Quality, 2 to 6 in fiber length, average 3.5 in
4th Quality, Noils. the short fibers resulting from the dressing operation They are spun into coarse yarns on special machines and the yarn so obtained is used principally in weaving yarns and for electrical insulation

Silk noils are also used to a large extent in wool mixtures. The woolen and worsted trade uses more spun silk than any other type of silk yarn Spun silk yarns are used extensively to produce pin stripes in fine worsted mens-wear and to create novelty effects and patterns in ladies dress goods Some of the finest and most expensive cashmere duvetyns and velvets have a warp of spun silk and a filling of cashmere noils

The numbering system for the spun silk yarns is based on 840 yards

per pound One of the most suitable yarn numbers for mens-wear pin stripes is the 54's, which is generally used as a 2-ply yarn of two 108 single yarns

Silk noils and other wastes from the spun silk operations are utilized in woolen blends to add strength and luster to various fabrics Of the regular silk yarns, organzines are occasionally twisted with very fine single worsted warp yarns to give additional strength for the weaving processes

Tussah silk In addition to cultivated silk, there are a number of wild silks, of which *Tussah* is the most important Tussah and other wild silks are the products of the larvae of wild moths The cocoons are much larger, but less regular than those of the *bombyx mori* Reeling is extremely difficult and seldom attempted The fibers are much thicker and less uniform in diameter than true silk and frequently show a twisted appearance They also have a large number of longitudinal striations. Because of their greater thickness they possess great strength Tussah silk is of interest to the wool man because of its peculiar luster It is used occasionally in small percentages to obtain a glittering effect in velours, duvetyns and suedes

COTTON

Cotton constitutes an important adjunct to the woolen manufacturer both in the raw fiber as well as in the yarn state It is interesting to note that the use of cotton in woolen manufacturing has increased rather than decreased In 1945 a total of 4 million pounds of cotton in various forms was consumed

Cotton is a seed fiber from a small bush plant termed botanically, *gossypium* It is grown principally in the United States, India, China, Russia and Egypt The American varieties of cotton are Sea Island, American Egyptian, long staple Upland and short staple Upland, in the descending order of their staple lengths, which range from 25 inches to ⅞ of an inch The principal points taken into consideration in grading cotton are length, fineness, strength, pliability, color and cleanliness As with wool, the United States Department of Agriculture has established definite cotton grades There are seven main grades, six quarter, six half and six three quarter grades

Physical Properties Under the microscope the cotton fiber appears as a twisted flattened tube The number of twists varies considerably with the kind of cotton, and is greater in cultivated than in unculti-

Fig 8 Longitudinal and cross section of cotton (X500) *Reumuth*

vated cotton. The cross section of the fiber shows a thin wall and a large central canal or lumen. (Fig 8) Certain fibers have no lumen and are white and stiff These are the unripe or immature fibers.

Fineness As in other textile fibers, the fineness of cotton varies between the many species as well as within similar species grown in different parts of the world The average widths may range from 10 to 40 microns Width measurements made on samples from the U. S Department of Agriculture are shown in Table 8

TABLE 8 WIDTH MEASUREMENTS OF COTTON FIBERS

Types	*No of Fibers*	*Average Width Microns*	*Coefficient of Variation per cent*	*Dispersion Range Microns*
Sakellarides	200	16 4	18 7	8-26
American, Egyptian	300	16 2	20 9	6-26
Fine American, Upland	200	17 1	22 4	8-27
Coarse American, Upland	200	19 2	21 2	8-30
Indian	400	21 2	18 8	10-33

In comparison with wool, most cotton types are finer than 80's wool The ribbon-like form of the cotton fiber is best seen from the cross measurements given in Table 9, which shows the maximum and minimum diameters as well as the ratio between the major and minor diameters. (The major-minor ratio represents the average of a series of quotients, and not the quotient of the maximum-minimum average)

TABLE 9 CROSS SECTION MEASUREMENTS OF COTTON FIBERS

Types	*Diameters in microns Maximum*	*Minimum*	*Ratio Major/Minor*
Very fine .	16 73	6 20	3 07
Fine American Upland .	20 02	7 83	2 77
Coarse American Upland	24 97	9 49	2 90
Very coarse Asiatic ..	27 26	14 57	2 07

Cotton is used with wool in fabrics to lower costs as well as to impart some of the desirable properties of cotton, such as high strength, to the wool product This is generally accomplished by one of three distinct methods:

(a) By mixing the fibers in the raw stock for woolen yarns
(b) By blending with top to produce mixed worsted yarns
(c) By using in yarn form, either pure or plied together with worsted and woolen yarns, as warp or filling in weaving or as decoration.

Because of the difference in fiber length and physical behavior certain precautions are necessary to bring about proper blending in mixing raw cotton with scoured wool before spinning It is very important that the wool be oiled separately before the two materials are blended in the mixing picker In worsted spinning (French system) where wool top is blended with cotton sliver, the various drawing machines have to be set more closely to compensate for the short cotton fiber

Cotton yarns are used extensively in warping and weaving to produce warps for broadcloth, bolivia, velours, blankets and shirtings Numerous fleece overcoatings have a cotton yarn backing In making double or triple cloths, as well as blankets, cotton binder or stitching threads are employed and cotton yarns are used as filling in some of the gabardines and venetians In the cheaper men's wear suitings, fine cotton yarns are extensively used, twisted with worsted yarns in warp as well as in filling Very popular also are piece-dyed coverts used for top-coatings where the white warp effect is produced by the presence of fine white cotton yarns twisted with worsted yarns Fine mercerized cotton yarns are used extensively for striping in mens wear fabrics

The cotton yarn number is based on 840 yards per pound The following cotton yarn numbers are a good cross section of the cotton yarns used For knitted backings in fleece overcoatings—12 to 16s, for warps in broadcloth, bolivia and blankets—1/14 to 1/20, for men's wear suitings—26/2 to 30/2, gabardine filling—30/2 to 60/2 and for stripings—120/2 mercerized cotton

Mercerized cotton.—Mercerized cotton is characterized by the high luster brought about by treatment of the fibers under tension in a concentrated caustic soda solution Observed under the microscope, full mercerized fibers resemble silk in their lack of structural detail In cross-section they exhibit a full round to oval shape with the lumen either as a thin short line or a tiny hole in the center of the fiber [1]

[1]Werner von Bergen and Walter Krauss, *Textile Fiber Atlas* (New York Textile Book Publishers, 1945), p 26

Bast fibers In addition to cotton there are employed in combination with wool other vegetable fibers belonging to a group known as bast fibers, such as flax or linen, hemp, jute and ramie.

The bast fibers are not used to any great extent in woolen and worsted dress goods and men's wear Their greatest use is found in the making of the back structure of carpets and rugs (See Chapter 21)

RAYON FILAMENT AND STAPLE FIBERS

The word rayon has been in use since 1924 as a generic name for a group of man-made fibers made by four distinct processes Previously rayon had been known by various names such as "artificial silk" and "wood silk", as well as by special brand names. In 1926 the A.S.T.M. adopted the name rayon and defined it as . "A generic term for filaments made from various solutions of modified cellulose by pressing or drawing the cellulose solution through an orifice and solidifying it in the form of a continuous filament" In 1937 the Federal Trade Commission promulgated the Rayon Trade Practice Rules Under these rules the term rayon is defined as "the generic term for manufactured textile fiber or yarn produced chemically from cellulose or with a cellulose base and for thread, strands or fabric made therefrom, regardless of whether such fiber or yarn be made under the viscose, acetate, cuprammonium, nitrocellulose, or other process".

Rayon was invented in Europe at the end of the 19th century and was produced there for some time before its introduction into this country in 1910 While originally intended to imitate the expensive natural silk, it has now earned a place second only to cotton among the important textile fibers Its world production climbed from 33 million pounds in 1920 to approximately 3½ billion pounds in 1942 In 1939 it surpassed the world wool production for the first time, thus attaining second position among fibers used for clothing purposes.

In the manufacture of rayon, three methods are generally used In the order of their commercial importance they are 1) the *viscose* process, 2) the *cellulose acetate* process and 3) the *cuprammonium* process A fourth process, the *nitrocellulose* process has not been used since 1934 in the United States The methods for making rayon differ considerably according to the process used However, as implied in the definition, the following three steps are basic:

(1) Cellulose is changed into liquid form
(2) The liquid is drawn out into very fine strands
(3) These viscous strands are converted to solid cellulose filaments

and combined into continuous yarn, or made into short lengths known as "rayon staple fiber" Brief descriptions of the three basic processes for making rayon follow.

Viscose rayon process In the viscose process the filament or fiber is spun from a viscous liquid made from regenerated cellulose with the aid of water and various chemicals To make one pound of viscose rayon, 1 15 to 1 25 pounds of wood pulp and/or cotton linters are necessary. Before the cellulose is in solution and ready to go into the spinning bath, the following steps are necessary *First,* the pulp is mercerized until it is a pure alpha-cellulose, known as alkali cellulose, *second,* the alkali cellulose is shredded and then aged, *third,* its chemical form is changed as it is churned with carbon disulfide and converted to cellulose xanthate It is then matured, and dulling agents are added, if desired. When the resultant syrupy liquid has been carefully filtered and deaerated, it is ready to be spun into filaments

The spinning solution is pumped through a spinneret which is immersed in a hardening bath (The spinneret is a cap of special metal about half the size of a dime, in which there are many tiny holes) As the spinning solution emerges from the spinneret holes into an acid hardening bath, it coagulates into fine solid filaments, the number of which is determined by the number of holes in the spinneret A single spinning machine consists of many spinnerets immersed in a hardening trough through which the acid flows continuously

In the production of continuous filament rayon yarn the filaments, as they leave the hardening bath, are carried up over a series of rotating glass wheels which stretch and guide them down to a collecting bucket or pot The pot, which rotates at high speed, imparts a slight twist to the yarn, and forms it into a cake The cake of yarn is desulphured and washed, then bleached, washed and dried It is then ready for winding into cones or other packages desired by the textile mills The entire process, including the making of the yarn, takes about one week

Cellulose acetate rayon process Purified cellulose from cotton linters is steeped in acetic acid and then allowed to age or mature The aged pulp is mixed with acetic anhydride, and goes into solution as a salt, cellulose acetate The solution is a clear, thick liquid After further aging, the cellulose acetate is precipitated in the form of pure white flakes by running the thick liquid into water The flakes are then washed and dried Next, the flakes are dissolved in acetone to form the spinning solution, which is clear and has about the same consistency as molasses syrup

As in the case of the viscose process, the spinning solution is forced through holes of a spinneret to form filaments of rayon From the holes

of the spinneret, the streams of filaments are conducted down through a shaft where they meet warm, humid air. The acetone evaporates, leaving continuous filaments of acetate rayon The collected filaments are given a slight twist and the resultant continuous filament yarn is wound into the various forms required by the textile mills

Cuprammonium process Cellulose is dissolved in a solution of copper sulfate and ammonium hydroxide The solution is then aged and filtered, after which it is ready for spinning. The spinning solution is pumped through a spinneret As the tiny streams pass through the hardening bath, they solidify into fine filaments After the yarn is washed, soaped and dried, it is ready for use During the process the filaments are sufficiently stretched to reduce them to the proper size or denier.

Rayon yarns are produced in two forms, namely, as a continuous filament yarn and in a fibrous form, known as short staple fiber Rayon staple fibers have found an increasing use in the woolen and worsted industry, whereas the smooth, long rayon filament yarns cannot be used to produce goods of a wool-like character.

Staple fiber. The first domestic rayon staple fiber was produced commercially by the viscose process in 1928 The operation consists of spinning rayon filaments and then cutting them into short, uniform lengths, which are spun by cotton, worsted or spun silk spinners into textile yarns, called spun rayon yarns The idea originated in Germany during World War I. It made no appreciable progress here until about 1929, but since that time it has had a phenomenal growth In 1929 the world production of viscose rayon staple fiber was a little over seven million pounds, whereas in 1941 it had reached the enormous total of over one billion pounds

In the United States its growth was slow at first, and it continued that way until 1935 Table 10 shows the increasing domestic produc-

TABLE 10 U S PRODUCTION, IMPORTS AND CONSUMPTION OF RAYON STAPLE FIBER

(In thousands of pounds)

Year	*Production**	*Imports*	*Available for U.S Consumption*
1930	350	518	868
1935	4,600	1,461	6,061
1940	81,098	17,736**	98,834
1945	168,400	2,400	170,800
1946	176,400	33,800	210,200

* Acetate and viscose staples combined ** Nine months only

tion, imports, and total consumption of staple fiber, principally viscose fiber, in five periods from 1930 to 1945, and through 1946

No exact figures are available for the output of "wool" types of rayon staple fiber, which are comparable in fineness and length to the various wool qualities It is estimated that the wool type represents about one quarter of the total world staple fiber output, the other three quarters being produced in the cotton type

The present trend in rayon staple fiber is to simulate the main physical characteristics of wool such as fineness, length, crimpiness, luster and strength Today the staple fiber is produced in various finenesses, namely, 1½, 3, 5, 8, 10, 12, 16 and 20 deniers and in lengths of from 1½ to 5 inches, to correspond to the various grades of wool The curves in Fig 9 show which type of viscose and acetate staple fiber compares most closely with a given wool quality.

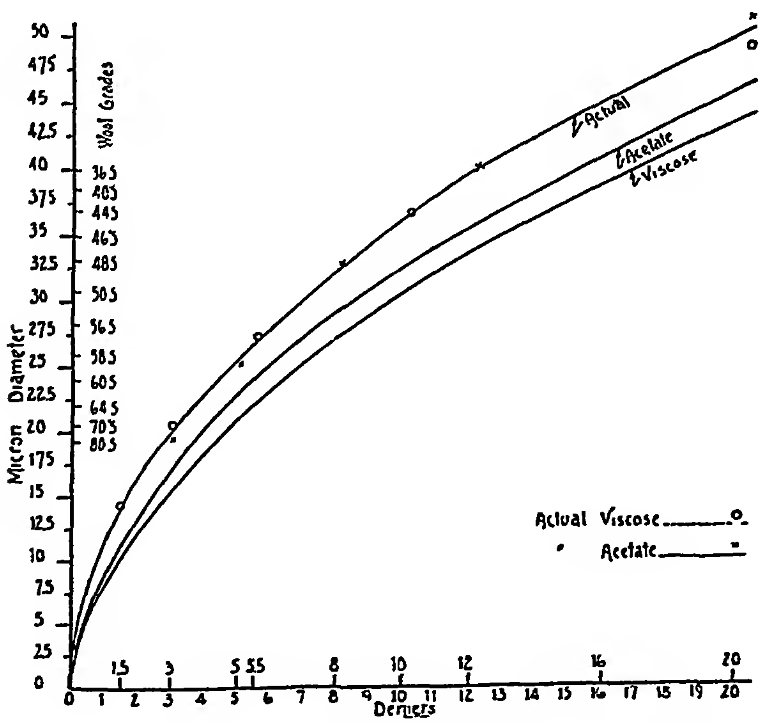
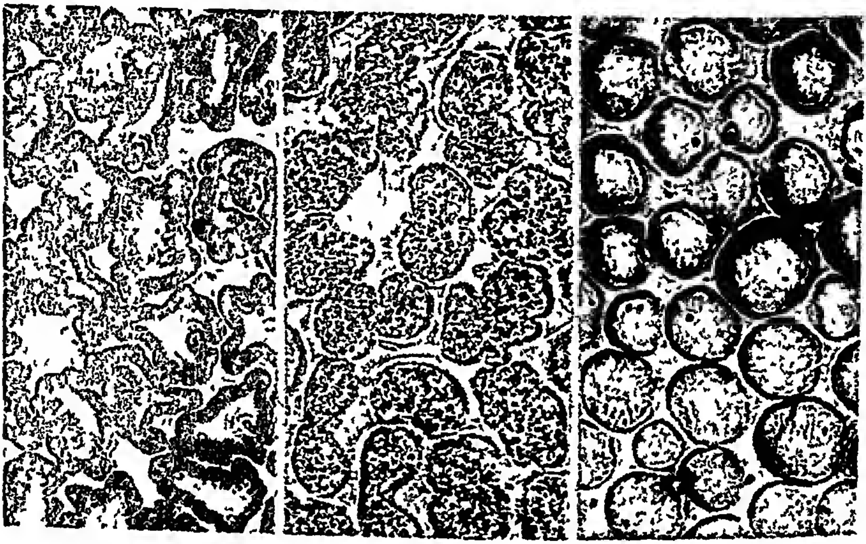


Fig. 9 Relation between theoretical and actual width of viscose and acetate staple rayon compared with wool grades

Physical and chemical characteristics Rayon exhibits the same properties whether in continuous or cut form, varying only according to the process by which it is made. Because it is primarily cellulose, it exhibits many properties similar to those of cotton. Microscopically, the different types of rayon fibers can be identified readily by the shape of their cross sections. (Fig. 10)



5½ den viscose (dyed) Dupont Av 27 5m | 5 den acetate (dull) Tenn East'm Av 25 5m | 3 den cuprammonium Bemberg Av 20 5m

Fig 10 Cross sections of rayon staple fibers (X 500)

As the microphotographs show, the cross sections of rayon filaments are of varying shapes The factors responsible for their shape are the nature and strength of the coagulating bath, the size of the orifice and the degree of stretch after coagulation In viscose rayon the contour is the most irregular, the acetate shows rounded curves in its cross section, whereas the cuprammonium is nearly circular

Both rayon yarns and staple fiber are now made in bright luster and in varying degrees of dullness, to resemble as much as possible the color and luster of wool This delustering is achieved by the addition of titanium dioxide to the spinning solution. The dull rayon filaments are easily recognized in cross section by the presence of little black dots, caused by the metallic dulling agent

Fineness When the filaments are measured according to the standard test method for fineness of wool[2], the following facts can be estab-

[2] A S T M Designation D 419 44

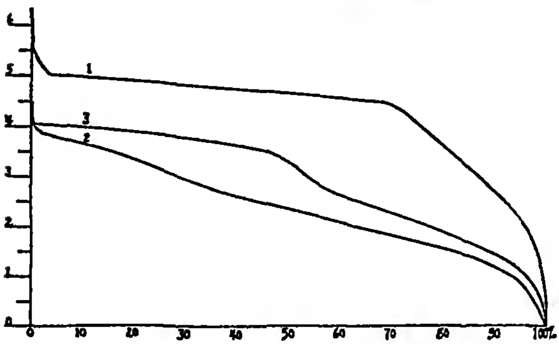
lished. (1) The rayon staple fibers are by far more uniform than wool The dispersion range is much smaller and, therefore, also the per cent variation as shown in Table 11 (2) The measured width of the viscose and acetate rayon is considerably higher than the theoretical value as can be seen from the chart, Fig. 9, which compares the curves for the theoretical fiber width with the curves found by actual measurement of the fiber width

TABLE 11 WIDTH MEASUREMENTS ON RAYON STAPLE FIBERS

Number of Fibers 200

Denier size	*Average microns*	*Standard deviations microns*	*Standard error microns*	*Co-efficient of variation in percent*
		Viscose Staple Fibers[1]		
1 5	14 45	2 16	15	14 0
3	20 55	2 35	16	11 4
5 5	27 35	3 40	23	12 4
10	36 80	5 25	37	14 2
20	49 45	6 95	48	14 0
		Acetate Staple Fibers[2]		
3	19 55	2 48	17	12 6
5	25 17	3 40	24	13 5
8	32 88	3 91	27	11 8
12	40 03	5 87	41	14 0
16	45 00	6 43	45	14 0
20	51 55	7 51	53	14 5

[1] Courtesy of American Viscose Corporation (Fibro fiber)
[2] Courtesy of A M Tenney Associates (Tennessee Eastman staple)



Types	*Av length Inches*	*Variation Per cent*
5-denier acetate 5″ staple	4 25	22 4
5-denier acetate 4″ staple	2 37	38 8
5-denier viscose 4″ staple	2 87	33 8

Fig 11 Length curves of rayon tops

These results are very valuable in establishing the grade of staple rayon present in finished fabrics in order to calculate back to the original blend It proves that wool measuring methods can be applied to grading the various staple rayons

Lengths Commercially the following lengths are the chief ones available 1, 1½, 2, 4, and 5 inches The length diagrams produced with the Suter wool stapler are charac-

teristic of all staple rayons and are illustrated in Fig. 11. They are easily distinguished from wool length curves.

Moisture content The moisture contents of rayon yarns and staple vary according to the process by which they are produced. Viscose and cuprammonium rayons have about the same moisture content as wool, whereas acetate rayon has a much lower moisture content At 65 per cent relative humidity and 70° F, moisture contents are as shown in Table 12

TABLE 12 MOISTURE CONTENT OF VARIOUS RAYONS IN PERCENT

Types	*% moisture*
Viscose	13 10
Acetate	5 95
Cuprammonium	12 45

The specific gravities of the different rayons vary according to process, i e, for acetate 1 33, and for viscose and cuprammonium 1 53. The specific gravity of wool is 1 30 which means that acetate rayon has nearly the same weight as wool per volume, one reason why it mixes well with wool

The regenerated cellulose products are, in general, less resistant to heat than the vegetable fibers such as cotton and linen While viscose and cuprammonium rayons burn like cotton, cellulose acetate burns much like wool, leaving charred ends or globules, though the odor is quite different The fire hazard in mills handling rayon staple fiber is no greater than that involved in handling cotton

Chemical properties. The chemical behavior of viscose and cuprammonium rayon is much like that of cotton Strong acids are harmful and destroy them by carbonization They are highly resistant to alkalies Acetate rayon, being a cellulose ester, is much more resistant to acids and will even stand carbonizing with aluminum chloride or hydrochloric acid Carbonizing with sulfuric acid, however, even though it does not destroy the acetate, tenders it to a damaging degree When acetate must be removed, it is necessary to pre-saponify it with alkalies

Frequently mixtures of two or more alkalis are employed for saponification For example, one formula consists of two pounds of caustic soda (76%) and eight pounds of trisodium phosphate dissolved in 100 gallons of water. The material is treated in this solution for one hour at 140° F

NEWER DEVELOPMENTS

Improvements, especially of the rayon staple fiber, are coming so rapidly that many of the properties described above are changing continuously, and it becomes increasingly difficult to record them completely. Recently, staple fibers have been produced with a crimp approaching that of wool which, while lessened during manufacturing processes such as carding and gilling, is regained by steaming the yarns or goods. This brings the staple fiber still closer to the general characteristics of wool. Anther development utilizes the incorporation of nitrogen-containing compounds such as casein and other proteins, thereby altering the chemical characteristics, as well as the dyeing properties, to such an extent that regular wool dyes can be employed.

The creasability of a fabric which contains a large per cent of staple fiber is found to be far greater than in woolen piece goods. Of late this defect is being overcome, largely by the application of synthetic resins to loose staple fiber, as well as in finishing the goods. The use of staple fiber in woolen and worsted piece-goods has already reached considerable proportions. It has been estimated that 25 percent of all ladies' dress goods and children's wear today contains large proportions of staple fiber. In the production of men's wear, both viscose and acetate staple fiber have been used for summer sportswear such as slacks, jackets and shirts. However, in men's suiting the fiber has not found wide use so far.

Casein fibers. The year 1935 saw the introduction of the first synthetic wool produced from milk or, specifically, *casein*. It originated in Italy and was given the trade name *Lanital*. The inventor is Antonio Ferretti, whose patents are being commercialized by the Snia Viscosa interests, the largest producer of rayon and staple fiber in Italy.

The spinning equipment is the same in principle as that used for the conversion of wood-pulp into rayon. The casein is extracted from skimmed milk in the usual manner and after extraction it is dissolved in an alkali bath. The paste formed is squeezed through exceedingly fine holes or spinnerettes and the extruded *vermicelli* passed through a condensation and hardening bath of formaldehyde and other chemicals which assist in the process. To give the continuous filaments a wool-like appearance they are cut into lengths similar to staple fiber. One pound of casein makes roughly 1 pound of casein staple fiber.

American development. In this country, Earle O. Whittier and Stephen P. Gould in their U. S. Patent No. 2,140,274 of December 13, 1938, and later No. 2,204,535, of June 11, 1940, offered a process of

making casein fiber and assigned the patents for public use. So far as is known, no commercial fiber has been made as yet by this process.

American commercial development of casein fiber has proceeded from work on casein originated by the Atlantic Research Associates, Inc, of Newtonville, Mass (The initials *ARA* from this company's name are found in the trademark of the commercial American casein fiber *Aralac* and in the name of several novel processes used in its manufacture) Today, the sole domestic manufacturer of casein fibers is Aralac Inc, a division of National Dairy Products, Inc This company started production in Bristol, R I in 1939 with a daily output of 4,000 pounds.

In July, 1941 the plant was moved to Taftville, Conn, where it attained an output of 15,000 pounds per day It has doubled its capacity since and, in 1943, it had a capacity of 30,000 pounds daily or 10,000,000 pounds yearly It is asserted that this increase is due to the interest taken in the fiber by the woolen, worsted and cotton spinning trades A new *Arathermung* or acetylation process gives the fiber improved stability in boiling water and wet processing and also reduces dyestuff absorption

American casein fiber is sold most commonly in the form of loose staple fiber Aralac, Incorporated give the following chemical and physical properties for their product

Chemical and physical properties In chemical constitution and many of its physical and chemical properties, Aralac has a great resemblance to wool The chemical composition approximates that of wool (Table 13.)

TABLE 13 CHEMICAL COMPOSITIONS OF WOOL AND ARALAC
(in percent)

	Aralac	*Wool*
Carbon	53	49 31
Hydrogen	7 5	7 57
Oxygen	23	23 66
Nitrogen	15	15 86
Sulfur	0 7	3 6
Phosphorous	0 8	0 0

Physical appearance Aralac is a cream colored, soft staple fiber, with a semi-dull lustre It somewhat resembles wool, with an imparted crimp and a soft, wooly hand Under the microscope it appears longitudinally as smooth cylinders with slight striations and pigmentation and has a circular cross section

Length and fineness The staple fiber is manufactured in grades

approximating 50's, 60's and 70's wool, and in 15 micron (finer than any wool grade) and in any length from ½ to 6 inches

TABLE 14 ARALAC QUALITY AND GRADES

Grades	*Diameter (in microns)*	*Fiber Size (denier)*
50's	30	7
60's	25	5
70's	20	3
	15	1½

The dry strength of Aralac fiber is 12,000 psi at 70° F and 65 per cent relative humidity The wet tensile strength is approximately 40 per cent of that of natural protein fibers At standard temperature and humidity, the elongation is 12 to 15 per cent Elongation of Aralac is influenced by moisture and temperature and its elasticity is somewhat less than that of protein fibers The regain of Aralac at 70° F and 65 per cent relative humidity is approximately 12 6 per cent or a commercial regain of 13 per cent

Aralac swells when wetted out with water to a degree dependent on the pH of the aqueous solution (Table 15) In general, the higher the pH, the greater the degree of swelling

TABLE 15 ARALAC FIBER SWELLING

Fiber	*Solution*	*% swelling*
Regular, unneutralized	aqueous—pH 4	8
Regular, scoured	aqueous—pH 7	22
Regular, unneutralized	10% caustic	47

The fiber is insoluble in organic solvents and its specific gravity is established at 1 29, slightly lower than wool Its absorbency is a little greater than that of natural protein fibers, with a greater tendency to hold water Having a protein base, it burns with the same odor and bead formation as natural protein fibers

Aralac tends to accelerate felting. Because of its shrinking properties, elasticity and ease of deformation when moist or wet, it acts advantageously when blended in suitable percentages with wool and fur for felt manufacturing in conventional procedures

Aralac is subject to attack of the webbing moth and carpet beetles It may be mothproofed with many types of mothproofing agents

Effect of heat Aralac should be dried at less than 212° F because

drying at higher temperatures will cause harshness The presence of formic or acetic acid reduces the tendency towards harshness when the fibers are dried at high temperatures, whereas the presence of alkalies causes discoloration of the fiber

Effect of alkalies Aralac fibers, like animal fibers, are sensitive to alkalies, and may be dissolved by the action of strong alkalies At high temperatures strong alkalies dissolve Aralac in approximately one half hour, whereas animal protein fibers dissolve more quickly. Mild alkalies, such as di-sodium phosphate, sodium bicarbonate, borax, sodium tetrapyrophosphate, and other alkalies having a low pH, have no deleterious effect on the fiber unless used in high concentrations for prolonged periods at high temperatures

Effect of acids Aralac does not appear to undergo any appreciable change when treated with dilute acids. However, the acids are held tenaciously by the Aralac fiber, and cannot be removed entirely by washing with water When treated with dilute acids, and then washed, the Aralac fibers show increased affinity for direct and acid dyestuffs On neutralizing the acid-treated fibers, the fibers return to their original dye absorption properties Concentrated mineral acids, such as sulfuric, cause disintegration of the fiber, especially at high temperatures

OTHER MAN-MADE FIBERS

Nylon. Among the other new man-made fibers of interest to wool men and manufacturers, nylon holds an important place because of its great strength It was introduced to the American textile trade in 1938 by DuPont and found its first important use in women's full-fashioned hose It is truly an all synthetic fiber, being made from coal, air and water.

Nylon is the generic name for all materials technically defined as synthetic fiber-forming polymeric amides having a protein chemical structure similar to silk, hair and wool It is made from dibasic acid and a diamine and spun like rayon into fine continuous filament yarns or the filaments may be cut into short staple fibers and spun by the usual cotton, or worsted or spun silk systems It is distinguished by its extreme strength and can be drawn into very fine fibers and filaments with great uniformity of diameter It has high abrasion resistance, is essentially a dry fiber, very light, with a specific gravity of 1 14 against 1 30 for wool. It acts similarly to acetate on burning, forming a color-

less bead It absorbs about 4 per cent moisture at standard conditions It can be made in bright and dull luster and has good moth, insect and mildew resistance Mild acids and strong alkalies have no appreciable effect and nylon is readily soluble only in phenol or hot concentrated nitric, sulfuric, hydrochloric and glacial acetic acids It can be dyed with water-insoluble colors such as are used on acetate rayon. Shrinkage is controllable and a permanent set can be accomplished by steam In admixture with wool it has definitely good possibilities which have not as yet been fully explored

Its use in knitting yarns for the purpose of increasing wear and abrasion resistance by reinforcement in foot positions, as in socks, has proven highly valuable

TABLE 16 COMPARISON OF FINENESS, LENGTH AND STRENGTH OF NYLON STAPLE, NYLON AND WOOL TOPS

SIZE	*NYLON STAPLE FIBER*		*NYLON TOP*		*WOOL TOP*	
	3 den	*6 den*	*3 den*	*6 den.*	*64s*	*50s*
Fineness (average microns)	21.5	32.4	21.5	30.2	21.9	30.4
Co-efficient of variation in %	6.8	26.9	7.1	8.7	21.0	25.0
Length in inches	3		2.8	3.6	2.8	4.1
Co-efficient of variation in %			15.9	14.2	36.8	34.1
Strength. (Grams/denier)	4.7	3.0	4.0	5.0	1.3	1.6
Pounds/square in	67,900	42,000	57,370	72,040	22,246	27,065
Co-efficient of variation in %	5.7	9.3	5.2	2.8	2.3	1.3

Courtesy *Forstmann Woolen Laboratories*, (1946)

Table 16 shows a comparison of nylon staple and nylon top with wool top of the same fineness Uniformity of fineness and length is far greater in nylon than in wool Its strength is anywhere from 2 to 3 times greater than comparative wool grades

Nylon brushes are used in brushing and shearing woolens and

worsteds Of late, nylon *tow* has been produced for use in making effect threads of various combinations, twists and cords[3].

Vinyl resin fibers Another man-made fiber has been used to some extent in the manufacture of industrial felt and non-woven felt hats as well as knitted fabrics It was introduced in 1937 by the Carbide and Carbon Chemicals Corp. and, in 1939, the American Viscose Corporation produced it for the textile trade in the forms of filament yarn and staple fiber under the trade name *Vinyon*. Vinyon is a copolymer of vinyl chloride and vinyl acetate, produced by polymerization rather than condensation as are the phenol, urea and alkyd types of resins. It is spun similarly to acetate rayon and stretched considerably during this process It is easily identified by its dumbbell-shaped cross section.[4] It is a dry fiber, having less than one half of one per cent moisture at standard conditions Its specific gravity is 1 37, and acts very much like acetate rayon and is thermoplastic It fuses at 140° to 150° C or 285° to 302° F. It stretches from 18 to 20 per cent, depending on conditions of temperature, moisture and manufacturing procedure It is practically waterproof, not attacked by bacteria, fungi or mildew and will not support combustion It can be dyed readily with specially prepared acetate dyes, which are commercially available When a scarcity of rabbit hair occurred, vinyon was used as a valuable substitute and worked out well in women's and men's felt hats.

Soybean fiber Its nature and characteristics are similar to casein fiber Soybean fiber was made by the Ford Motor Co and used in automobile upholstery and fabrics of various types Toward the end of World War II Ford sold the facilities to the Drackett Company of Cincinnati, who is now producing soybean staple fiber and continues to offer it to the textile trade It has only about 80 per cent of the tensile strength of wool and is light tan in its unbleached state. It has a moisture regain of about 11 per cent and its density is 1 31, very close to wool. With further development and improvement the fiber has possibilities in admixture with wool for felts

Peanut protein fiber There has been considerable experimentation in England with a staple fiber made from peanut protein, which is very similar to soybean and casein fiber In this country, the fiber is being

[3]For detailed information on nylon fiber and yarns see J M Matthews and H R Mauersberger *Textile Fibers*, 5th edition (1947) New York, John Wiley & Sons, pp 855-875

[4]Werner von Bergen and Walter Krauss, *Textile Fiber Atlas* New York Textile Book Publishers, (1945), p 34.

produced in small quantities by The Virginia-Carolina Chemicals Corporation of Carteret, N J

Seaweed fiber Dry seaweed contains 15 to 40 per cent of alginic acid, a chain molecule of high molecular weight, consisting of B-d-mannuronic acid residues The sodium and calcium salts of this acid have been found to be suitable raw materials for the production of fibers

Up to the present, calcium alginate fiber constitutes the product of most commercial value It is readily produced by extruding sodium alginate solution into a weakly acid solution of calcium chloride containing emulsified oil It is highly satisfactory in all respects except for its solubility in alkali However, this property has been turned to advantage in the manufacture of crepes, astrakhans, twistless cotton fabrics and light weight worsteds

A limited supply of such super-light-weight worsted fabrics appeared in England in the spring of 1947 Made of pure wool, they weigh between one- and three- and one-half ounces per square yard Obviously, worsted yarns fine enough to produce such exceptional lightness of fabric would be too frail to stand up under the stresses of modern weaving To produce the fabrics, the worsted yarns are reinforced by twisting with a calcinate alginate yarn which has a strength comparable with that of viscose rayon After weaving, the alginate yarn is washed out, leaving an all-wool fabric

J B Speakman[5] discovered the process and a considerable amount of credit for development of the commercial use as reinforcing threads in yarn and cloth should go to Mr A Johnson of Courtaulds Ltd [6]

Other man-made fibers have been made from vinylidene chloride, egg albumin and feathers as well as chitin, corn and fibroin, but none has found any use in the woolen and worsted industry Attempts to produce a pure keratin or animal protein fiber have not been successful, hence it appears that wool will hold its dominant lead for some time to come as the most important animal fiber in the textile world

[5]Speakman, J B, *Beryllium alginate fibers* British Pat. 545 872 (Aug 1942)
[6]Johnson, A, Speakman J B and Cefoil, Ltd, British Pat 550,525 (Jan 13 1943)
*Tupholme, C H S, *Alginic Acid Textile Fibers,* Chem Eng News 20, 13 (July 10, 1942)

Chapter 7

GRADING AND PRODUCTION OF WOOL[1]

WOOL as a commodity of commerce is extremely complex, varies widely in its characteristics, and is one of the most difficult to classify and grade for the benefit of the trade While the variation in wool has some correlation with the types and breeds of sheep, wide variations exist within the breeds. Fleeces having the same fineness often vary greatly in fiber strength, spinning properties, length, and contents of grease and dirt. Soil, climate, and feed all have a far-reaching influence on the character of wool.

Fleeces of merino or Rambouillet sheep from some sections of the western range where grass is sparse and sandstorms are frequent, may shrink as much as 65 to 75 per cent or more, due to grease and dirt, when scoured or cleaned preparatory to manufacture Fleeces from sheep of these same breeds grown on excellent bluegrass pastures where sandstorms are rare, will shrink only 50 to 60 per cent Such characteristics as strength of fiber, spinning property, and length of staple are also affected by the conditions of soil, climate, feed, and care

To produce the many different kinds of woolen and worsted yarns and to secure the desired effects in finished articles, wool of an even character and a specified degree of fineness or grade is required It is obvious that a fine, lightweight fabric could not be produced from a coarse wool, nor would a fine wool be used to produce a rough cloth

Two important operations are carried on in the journey of the wool from its raw state to the finished fabric, the purpose of which is to group together wools of like characteristics. The first of these is the market operation of grading, in which whole fleeces are classed and graded into their respective grades The second operation is sorting, the breaking up of the individual fleeces into their various qualities This is usually done at the mill As most manu-

[1] Sections of this chapter are taken from J Merritt Matthews and H R Mauersberger, *The Textile Fibers*, 5th Edition, by permission of the publishers, John Wiley & Sons, Inc, New York

facturers confine their products to only a few kinds of yarns and fabrics, the number of grades of wool suited to their needs is limited.

Demands for specific grades are chiefly responsible for the separation of the fleeces into the different groups or grades Manufacturers are willing to pay a higher price to obtain wool containing only those grades which meet their requirements Therefore, graded clips usually bring a better price In order to dispose of wools to the best advantage, the seller must know the proper class and grade names, the shrinkage, and must be able to understand the published market reports.

GRADING OF WOOLS

Commercial grades of wool are based primarily on fineness, or diameter, of fiber Two distinct systems of nomenclature are used in the industry to describe the market grades of wool They are known as the blood or American system and the numerical or English system Terms like "fine," "half-blood," and "three-eighths blood," describing the fineness of wool, are of American origin, and their use is confined principally to this country It should be understood that the word "blood" is a wool-grade term and has no reference to the breeding of the sheep The numerical terms like 58s, 60s, 70s are used internationally and have for their basis the maximum spinning capacity of wool, or the finest possible count to which it can be spun The use of the numerical terms is comparatively recent in this country, except among importers of wool The fineness of wool can be designated more accurately by these numbers In view of this fact, it is reasonable to assume that the numerical system will be more popular as it becomes better known To correlate the two systems, the grade specimens used in the practical forms of the United States official standards for grades of wool carry the respective numerical terms and the corresponding terms used in the blood system

Official standards The United States Department of Agriculture issued the present standards for grades of wool, which are recognized by law, on June 18, 1926 These practical forms are made up in sets which can be obtained from the United States Department of Agriculture, Bureau of Agricultural Economics, Wool Section, in Washington, D C, by the payment of a small fee

Fig. 1. Official United States Standards for grades of wool (1/3 original size) Courtesy: U. S. Dept. of Agriculture.

Every wool grower, wool merchant, and all agricultural agents and teachers who are connected in one way or another with the wool industry should be in possession of such a standard box, which assists in distinguishing the different grades

There are two kinds of sets, each one placed in a cardboard box. One box contains a representation in part of the official standard for grades of wool, consisting of seven grades for purposes of grading wool in the fleece The seven grades constitute the practical divisions of the range in fiber diameter and are the basis of the work of the wool grader. The second type of set (Fig 1) contains the practical form of all twelve official standards for grades of wool, which may serve as the basis for sorting at the mill

Fineness Fineness in wool can be correctly designated by either system or by both systems, but the English (the numerical system) is more specific in several instances The terms "56s" and "three-eighths blood" describe the same grade of wool But in the case of "fine" the numerical system has three grades (64s, 70s, and 80s) to cover the qualities so designated Table 1 shows the designations of the market grades of wool in the two systems and correlates a term in the blood system with the numerical system

To the original standard of twelve grades in January 1940, a thirteenth grade—namely, 62s—was added This grade has been an accepted grade in the American top trade for years

TABLE 1

STANDARD UNITED STATES WOOL AND TOP GRADES

Fine	80s 70s 64s	Quarter-blood	50s 48s
		Low quarter-blood	46s
Half-blood	62s 60s 58s	Common	44s
Three-eighths blood	56s	Braid	40s 36s

The hand-knitting worsted yarn manufacturers and their trade organizations use an additional grade, namely, 52s-54s, representing coarse three-eighths-blood wool

Length The nomenclature in the blood system and the numerical system refers only to the relative fineness or the diameter of the

wool fiber Therefore, in order to indicate lengths, and to give the wool a more complete description, it is necessary to use other designations as well The terms describing the market groups or classes for lengths that are usually used when the wool is graded are: "combing," "French combing," and "clothing" The clothing lengths are also frequently referred to as "carding."

When fine wools, 64s or finer, are graded, they are normally separated into the three groups of lengths strictly combing, French combing, and clothing. Fine farm-flock wools originating in Ohio, Michigan, Pennsylvania, and West Virginia and of strictly combing lengths are designated as "delaine," whereas French combing of the same wool type is known as "baby delaine"

In the coarser grades it is customary to make only two groups, the combing and the clothing On very few occasions when an intermediate length is made in the quarter-blood (48s and 50s) grade or in the three-eighths-blood (56s) grade, it is sometimes designated as "baby combing" The wools from 46s down are all of combing lengths

As an illustration, the wool that is fine is either described as a fine wool or as a wool of a 64s, 70s, or an 80s grade, but with this description only, no opinion can be formed regarding its length. But when reference is made to fine combing wool or 64s, 70s, or 80s combing wool, it immediately becomes clear that the wool is not only fine but it also possesses good staple length and, therefore, has sufficient length to be combed to advantage

At present there exists no official standard which specifies the correct lengths for this term, but the trade commonly accepts the following designations for fine wools.

Clothing, under 1½ inches
French combing, 1½ to 2½ inches
Strictly combing, over 2½ inches

As wool increases in coarseness these lengths increase on the average of ¼ inch per grade Fine combing wools are often called "fine staple" wools

Grading in the United States

Grading of wool by the grower was very uncommon in the United States previous to World War I During the years from 1920 to

1939, however, there was a marked tendency on the part of those who pool or consign their wool to sell by grade With the federal government strongly supporting such a move after World War II, grading of wool may become a general procedure in the future Selling any commodity ungraded is bound, in the long run, to work to the advantage of the buyer, because he is naturally in a better position to judge the true value of ungraded commodities than is the average producer.

The grading of wool is usually done in warehouses, either at the large concentration points in the country, where the wool is grown, or where the wool is sold In the United States, these warehouses are located in the cities of Boston, Philadelphia, Chicago, St Louis and other cities in the Middle West and the South, as well as on the west coast in the cities of Portland, Oregon, and San Francisco The bulk of the domestic wool is graded in the Boston warehouses Wool in original bags is bought in increasing amounts by large mills These wool clips come from a few range states and are ungraded, but are still sufficiently uniform for marketing purposes In some instances a wool dealer, when purchasing a large amount of ungraded wool direct from the ranches, may send out his own wool graders and grade the wool at the shearing pen before shipping it east By sending representative samples of the various grades to the prospective customers the wool merchant may be able to sell the wool before it is shipped or while in transit, and thereby save the expense of warehousing

Following is a description of the warehouse grading as done at

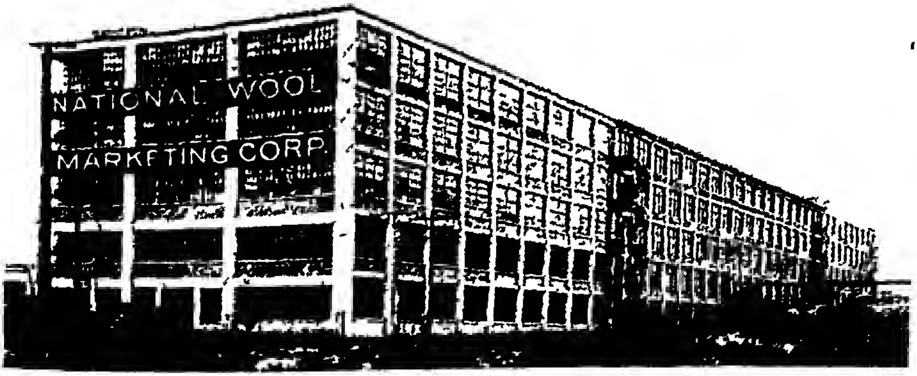


Fig 2 Modern Cooperatively-owned Wool Warehouse at Boston

Boston When a lot of wool reaches the warehouse, the bags are opened up and trucked one bag at a time to the grader. The working bench for the grader is a large wooden table which rests on wooden horses, allowing it to be moved and taken down easily Surrounding the table on two sides are large baskets on rollers The table is placed either under a skylight or in front of windows if possible facing north, the grader stands on the free side of the table and his only needs are a pencil and a notebook to check the lot number and bag number. To be a good grader it is essential to have good eyesight and an average memory; the grader's memory is the result of practice and experience, and enables him to make a quick decision about the grade of wool as represented in the fleece To have an official standard set on hand is an excellent aid for any grader The grader is assisted by two helpers, one to truck the bag to the table and the other to pass the fleeces one by one up to the table after the bag has been opened on the floor The grader opens up the tight fleece a trifle, pulling out small samples about the size of a lead pencil, from several places over the fleece. He tests it for strength by trying to pull it apart with his fingers and, using his thumb as a ruler, he estimates the length of the staple His eyes will note at a glance the fineness He then turns the fleece over to the other side and repeats the procedure If both sides are equal in grade and length he throws the fleece into a designated basket containing other fleeces of similar grade and length After the baskets are filled, they are removed and emptied onto a pile of fleeces of the same grade, where they remain until the entire lot has been graded If they have been sold, the graded wools are immediately rebagged and shipped Fleeces of the same grade, but of various lots, may be piled together and such graded piles before being bagged may contain as high as 5000 fleeces or approximately 40,000 pounds Great care is taken by the wool dealers in stacking the graded piles of wool attractively, because they believe that merchandise well displayed is half sold The piles are built upward as nearly straight as possible, with square corners

From these piles samples are drawn to represent the grade and sent to the various mills The wool buyers of large mills prefer to examine the wool in bulk and therefore they visit the wool storehouses to look over the whole lot The buyer is privileged to take out any fleeces which in his judgment do not belong to the pile This is called "drawing the fleeces" As this is done at the buyer's expense, he does it himself or sends an assistant to do the drawing

When the wool is approved, it is bagged and shipped according to the directions of the purchaser.

Wools that are graded in the West, the South, or any other concentration point and shipped to Boston for sale are seldom put into piles again. Sample bags are laid out on the floor or placed in a small pile for inspection. When the lot is sold, the buyer has the privilege of opening all the bags from the lot. He opens up one side of the wool sack, and, should any fleece in the bag be offgrade, it is pulled out and classified as a "reject." "Rejects" are faulty fleeces or those which have a limited market because of their color. Owing to careless shearing and tying the fleece may contain a large quantity of straw and seeds which have been picked up from the floor of the shearing pen. Then again the fleece may be burry or contain a large amount of vegetable matter which would require carbonizing. Wool removed from the carcasses of sheep which have died from illness or exposure, known as dead wool, black and gray wools, and cotted fleeces are all classified as rejects. Wools or fleeces from breeding rams of the merino type are also classified as a reject because of the excess amount of wool grease they contain, the shrinkage of such fleeces is higher than from ewes of the same grade.

Classing of Wool in Foreign Countries

In normal times the United States imports about 250 million pounds of wool annually; therefore, it is very important to know the various grades of foreign wools marketed in this country. The methods of grading and preparing the wool for the market in the great wool-producing countries of Australia, New Zealand, South Africa, and South America differ widely. These national methods will be described in the following pages.

Classing of wool in Australia. In Australia, the grading, or classing, as it is called, is done right at the shearing shed. The actual shearing is performed in the same manner as shearing in the United States, with the exception that the belly wool is usually shorn separately from the rest of the fleece. Special care is taken to protect the fleece from contact with foreign substances. The shearing room is presided over by the classer, whose job it is to separate the fleece into the various classes or grades, and to keep the wool of the same money value together as much as possible.

The classer is usually a man of technical training who has studied wool classing in one of the various agricultural colleges located throughout the country; he may be an employee of one of the large

wool houses An owner sometimes classes his own wool As the value of the clip depends largely upon the way in which it is classed, the classer's name goes on each bale so that he will be responsible for the quality in the pack Nearly all of the wool houses supply or recommend classers to their clients, feeling that this provides greater insurance of uniformity in the bale Classers are not licensed and their position depends largely upon their ability to sort wool properly. In classing wool the standards adopted by the British-Australian Wool Realization Association (Bawra) are followed in a much modified form

On being brought from the shearing floor the fleece is thrown, skin side down, on the wool classing table, so as to open widely The classing tables are about 7 feet wide and of various lengths, 8 to 9 feet or multiples thereof The table consists of a heavy frame, about 36 inches in height, with slatted bottom The slats are generally an inch in diameter and rollers at either end permit free action while handling the fleece They are spaced about ½ inch apart to permit short second pieces or dirt particles to drop to the floor.

Skirting is the next step, and consists of removing from the body of the fleece any objectionable sorts Two skirters usually work together at one table, one skirter operating on the front part of the fleece and the other on the hind part. The inferior portions or objectionable sorts are heavy shrinking parts such as tags, leg pieces, neck pieces, bellies, locks, and stained parts The various skirtings are separated by the skirters as follows. A small fragment of the wool skirted from the forequarters of the fleece is normally finer and of lighter shrinkage than the inferior "plucking" of the britch end They are known as "first pieces" and "second pieces" First and second pieces are looked over, together with the bellies and sweepings of the shearing floor, at the piece-picker's table. The tags, stained parts, and locks are sorted into individual bins. The piece-picker's table is 8 by 3½ feet and is sloped like a desk with the top made of slats, ½ inch apart, to allow dust, sand, and twice-cut wool to fall through.

The next step is the actual grading, determined by the wool classer himself as 70s or 60s super-combing or whatever grade it may be. The fleece is then placed in the bale assigned to that grade The fleeces from ewes, wethers, rams, and lambs are kept separate.

After skirting, the fleece is rolled with the cut side out and usually tied up by twisting in one end The best method of rolling the fleece is to have the flesh side of the fleece facing the table, then

turn in a little of the britch end and a little of the neck portion of the fleece After this, the side of the fleece farthest away is thrown toward the roller, making two folds The fleece is then rolled up from the britch to the neck

The packing is done with great care and the bales are reduced in size by the use of hydraulic presses The bales contain an average of forty fleeces and weigh 300 pounds Heavy jute bags are used which are singed on the inside to prevent loose jute fiber becoming mixed with the wool Each bale is plainly marked with the grower's name or brand and the grade of the wool it contains By this method the mill which receives the bale is able to identify the grower

The most common grades of Australian wool are

1. AUSTRALIAN MERINO WOOL GRADES

A A A Comb Extra Super Comb The longest, sound-stapled, lightest-conditioned, bright, fine fleeces the pick of the wool from the whole flock

A A Comb Super Comb (A A Merino) The *fleeces a little shorter in the staple* than the Extra Super Comb

A Comb First Comb (A Merino) The heavier-conditioned fleeces having a fair length of staple, value about 1*d* per pound less than the Super Comb

Comb Second Comb The shorter-stapled, tippy, and heavy-conditioned fleeces

B B Comb The lightest, strong-fibered, sound-stapled fleeces of about 58s/60s quality

B Comb Wool similar to B B, only heavier in condition, duller

A Fleece First Fleece Tender and very short staple fleeces, provided they are not too heavy in condition

Fleece A cast sort for any dingy or discolored wools or any very heavy conditioned or tender fleeces

A A Cloth Super Clothing The short, sound-stapled, light-conditioned, fine-fibered fleeces

A Cloth First Clothing Fleeces similar to the A A Cloth, but containing more yolk, etc, and black-tipped fleeces

A A Lambs Super Lambs The long-stapled and bright, fine lambs, free from burrs and seed

A Lambs First Lambs Shorter, heavy-conditioned lambs, including belly wool and odd seed

Lambs Second Lambs Very short, lamb locks, burry and seedy, kept free of urine stain

B Lambs Third Lambs Stained and crutching types or any black hairs

2 AUSTRALIAN CROSSBRED WOOL GRADES

Super Comeback Long sound-stapled fleeces, light condition, well-grown 60s quality and up

2 AUSTRALIAN CROSSBRED WOOL GRADES—*Cont*

A A Comeback Long sound-stapled fleeces, light condition, well-grown 58s quality

A Comeback Short heavy condition, not so well grown, seconds of Super Comeback, A A Comeback, 58s quality and up

A One-Quarter Bred Good stapled fleeces, light condition, well-grown 56s quality

A One-Half Bred Good stapled fleeces, light condition, well-grown 50s quality

A Three-Quarters Bred Good stapled fleeces, light condition, well-grown 46's quality

B Crossbred—Heavy short reject fleeces, also tender, that are not suitable for above

C Coarse Crossbred Strong coarse fleeces of 40s quality

A A A Lambs Fine comeback, quality 58s/64s, super style, color, and length Free of burrs

A A Lambs The firsts of the fine Crossbred Lambs' fleeces, of 56s to 58s quality, long-stapled, bright, and free from burrs or seed

A Crossbred Lambs The firsts out of the Crossbred Lambs' fleeces, of 46s to 50s quality, long-stapled, bright, and free from burrs or seed

B Crossbred Lambs The seconds of the A Crossbred Lambs, also the seconds of the A A Lambs

Lambs The short, stained, fatty, and fribby ends, and lambs' locks and black hairs

3 AUSTRALIAN PUREBRED LONG WOOL GRADES

A A Lincoln Leicester The bright, long, free, and sound-stapled fleeces of 40s quality

A Lincoln Similar wool to A A Lincoln only heavier in condition, also a little coarser Quality 40s to 36s

Lincoln Fleece Cotted and hairy fleeces of 40s and 36s quality

4 AUSTRALIAN OFF-SORTS WOOL GRADES

Necks, first and second pieces, bellies, locks, crutchings, black wool, dead wool

Classing of wool in New Zealand Wool classing in New Zealand is similar to Australian wool classing Because of the smaller average size of the flocks, however, it is not customary to make as many sorts The wool is skirted, belly wool is kept by itself, as are the leg wool, neck wool, breech wool, and crutchings These with the small bits of good wool, which drop from the fleece in classing, constitute the grades of wool as it comes from the farm. The following classifications are generally found. (1) skirted fleeces

marked according to grade; (2) bellies; (3) necks, (4) pieces; (5) breech wools; (6) crutchings or tags

Classing is done in very large holdings; usually about all that is done with the smaller clips is to remove the belly wool, the seedy or burry portions, and the crutchings. Each sort is packed in a separate bale, which is labeled with the brand of the owner and the type of the wool it contains The bales weigh about 400 pounds each Many of the owners of the small flocks make no effort to class their wool, they pack it lightly in bales and bring it to the broker's warehouse There the bales are opened and the wool is classed and then mixed with wool of similar grade After the grading, this mixed wool is repacked under a new name adopted by the broker This method of grading by the wool broker is called "binning," and the process is similar to that followed by the Co-operative Wool Association in the United States in grading small lots

Classing of wool in South Africa The classing of wool in the Union of South Africa is not as elaborate and as thorough a process as in Australia or New Zealand Only about 40 per cent is considered well-classed, the remaining being merely skirted to a greater or less degree, some fleeces being packed with no skirting at all The government of the Union is devoting considerable money and effort to bringing about a more uniform preparation of the clip for the market The main difficulty is the lack of trained and experienced wool classers The sorts made are similar to those of Australia Some wool is sheared every six months so that the staple is short and, therefore, can only be classed as "clothing" wool About 60 per cent of a twelve-months' clip is classed as "French combing," with lengths of 2 to 2½ inches The bulk of the wool is practically all merino and is classed as 64s to 70s, with a considerable quantity of 80s.

Classing of wool in South America The wool growers in South America, especially in Argentina and in Uruguay, are fast adopting the Australian method in preparing the wool for the market Better wools are usually skirted and baled without tying the fleeces

In Argentina, where Buenos Aires is the wool center, the sorts are designated as B A—Buenos Aires Wool The various grades are distinguished by numbers one to six Long wools and low crossbred wools make up 75 per cent of the clip in Argentina. In the provinces of Santa Cruz and Chubut, finer grades are raised

which are classed by themselves and under these names. The most desirable South American wools for the woolen and worsted industries are the Montevideo wools grown in the country of Uruguay Compared with English and American wools, the main grades are as follows

TABLE 2

GRADE CLASSIFICATION OF SOUTH AMERICAN WOOLS

	Argentina and Uruguay	*English Equivalent*	*United States Equivalent*	
Merino	Superior	80s	80s	
	Bueno to superior	70s	70s	Fine
	Bueno to corriente	64s	64s	
	Corriente	60s	62s	½ Blood
Cruza fina	Primera cruza	58s	58s to 60s	
	1	56s	56s—⅜ Blood	
	1 to 2	50s to 56s	—	
	2	50s	—	¼ Blood
Mediana	2 to 3	48s to 50s	—	
	3	48s	—	
	3 to 4	46s to 48s	—	Low ¼ Blood
Gruesa	4	46s	—	
	4 to 5	44s		Common
	5	40s to 44s	—	
	5 to 6	40s	—	
	6	36s	—	Braid
	6 to 7	32s	—	

Source Pablo Link, *Lanares Y Lanas*, (1938), p 182

CLASSES OF SOUTH AMERICAN WOOLS

Supras	Super	Well-skirted attractive wool of good quality
Primeras	First quality	Sound, clean, well grown
Segundas	Inferior	Less attractive wool, burry and faulty

Concordia wools from Argentina are similar to Montevideo wools. They receive their name from the city of Concordia on the Uruguay River. Another desirable wool is produced in the extreme southern end of South America in the country of Chile It is the Punta Arenas named after the seaport city from where the wool is shipped It runs normally from 50s to 56s in grade, and is classed according to the English system

Evaluation of Shrinkage

Probably the most important factor in determining the value of wool, especially in the United States, is its shrinkage In inspecting raw wool, the first duty of a buyer is to estimate the yield of "clean" or scoured wool Domestic wools may shrink in scouring from 25 to 80 per cent, meaning that 100 pounds of raw wool may yield 20 to 75 pounds of clean wool Since more than 300 pounds of grease wool may be required to produce 100 pounds of scoured wool, the importance of shrinkage, from the buyer's viewpoint, is easily appreciated.

Shrinkage is the result, first and chiefly, of the wool grease and yolk present in varying quantities in every natural wool. The fine-wool sheep carry much more wool fat in their fleeces than the breeds of the medium or crossbred type A big difference also exists between the fleeces of the ewes and the rams in regard to the fat content The ram fleeces have a much higher wool fat content and, therefore, a higher shrinkage For Texas wools, the grease content runs between 20 and 25 per cent in the ewe fleeces and from 40 to 50 per cent in the ram fleeces Second, shrinkage is a result of sand, dust, and dirt, which make up a great percentage of the foreign matter later lost in scouring A third factor influencing shrinkage is the presence of vegetable matter such as seeds and burrs, which necessitates a carbonizing process, in addition to the scouring, to remove them The proper shrinkage can only be ascertained by actual scouring of the whole lot or a sample representing the lot

Experienced wool buyers are supposed to estimate within 1 per cent of the actual shrinkage To attain such accuracy takes many years of experience and knowledge of the actual mill shrinkage of the same type of wool, or the same clip, for several years back The buyer cannot rely on the judgment of others, but must handle many fleeces right at the shearing shed or from the stockpiles, to estimate the average shrinkage for a whole lot The individual fleeces in the same clip or pile may vary 10 per cent or more from the estimated average A careful wool buyer also studies the weather conditions in the locality where the wool was grown

Price and shrinkage All grease wools are purchased on the "clean value," or clean cost, i.e , the actual market value of the wool after all foreign matter has been removed by scouring Since the wool growers quote their prices in the grease, the buyer is able on the basis of the shrinkage to calculate the clean cost For example, the

seller is asking 42 cents for his grease wool The buyer estimated this wool shrinkage as 60 per cent or a yield of 40 per cent In order to find the scoured price, the following formula is applied:

$$\text{Scoured wool price} = \frac{\text{Raw wool price}}{\text{Yield}} \times 100$$

or, in the example cited:

$$\text{Scoured wool price} = \frac{\$0.42}{40} \times 100 = \$1\ 05$$

In the opposite case, when the wool buyer knows that the value of a certain grade of wool is $1.05 a pound, scoured on today's market, he is able to find the value of this wool in the grease by the following formula

$$\text{Raw wool price} = \frac{\text{Scoured wool price} \times \text{yield}}{100}$$

In the example shown above, it would be:

$$\text{Raw wool price} = \frac{\$1.05 \times 40}{100} = \$0\ 42$$

Transportation charges must be added to the grease price.

The average fleece weight for all United States wool has increased from 6 8 pounds in 1910 to 8 pounds in 1940, whereas the average shrinkage for the same thirty-year period has fluctuated not more than 3 per cent, namely, between 59 and 62 per cent From 1933 to 1940 the shrinkage was 61 per cent, indicating that the changes from year to year are very small and in no instance was there more than 1 per cent between successive years This average figure for the whole country is not of much value to the wool buyer or the farmer, because of the tremendous variation between wools from the various states and ranges Of far more value to them is a knowledge of the various shrinkages for each state or, even better, for the various sections in each state, and also the relationship which exists in the shrinkage between the various grades

Table 4 shows the main United States wools, their shrinkage and fleece weight for the five-year period 1937-1941. It has to be remembered that these figures include all the wools—fine, medium, and coarse—in each state.

TABLE 4

SHRINKAGE AND FLEECE WEIGHT OF PRINCIPAL U S WOOLS

Farm States				*Range States*			
Domestic Wools				*Range Wools*			
States	*Shrink-age (per cent)*	*Weight per Fleece (pounds)* *Grease*	*Clean*	*States*	*Shrink-age (per cent)*	*Weight per Fleece (pounds)* *Grease*	*Clean*
Ohio	54	8 1	3 7	Wyoming	68	9 6	3 1
Pennsylvania	51	7 5	3 7	Montana	64	9 5	3 4
West Virginia	48	5 1	2 7	Idaho	62	9 5	3 6
New York	50	7 3	3 7	Colorado	64	8 3	3 0
Michigan	54	8 0	3 7	New Mexico	68	7 9	2 5
Vermont	48	6 7	3 5	Arizona	64	6 4	2 3
Indiana	45	7 4	4 1	Utah	66	8 9	3 0
				Nevada	66	8 2	2 8
				Texas	62	7 9	3 0
				California	62	7 1	2 7
United States	61	8 0	3 1				

Source U S Department of Agriculture

A simplified wool price chart (Fig 3) to calculate wool prices has been worked out by S. H Hunt of the University of Wyoming The chart shows the relation between the clean price of wool in Boston, the grease price in Boston and at the ranch, and the shrinkage. The following directions are given for its use.

1. Determine or estimate the wool shrinkage and the grade
2 Find the clean price of the wool at Boston
3. Lay a rule across the chart with edge crossing the determined shrinkage on the left side and the clean price of wool at Boston on the right side
4 Where the rule intersects the center line the grease price of the wool can be read Shrinkage figures are in per cent. Price figures are in cents

For example. A wool has an estimated shrinkage of 65 per cent and is 64s in grade The clean price in Boston is found to be $1 10. By linking the 65 on the left with the number 110 on the right the range price of the wool is found to be 34 cents or 39 cents grease price in Boston

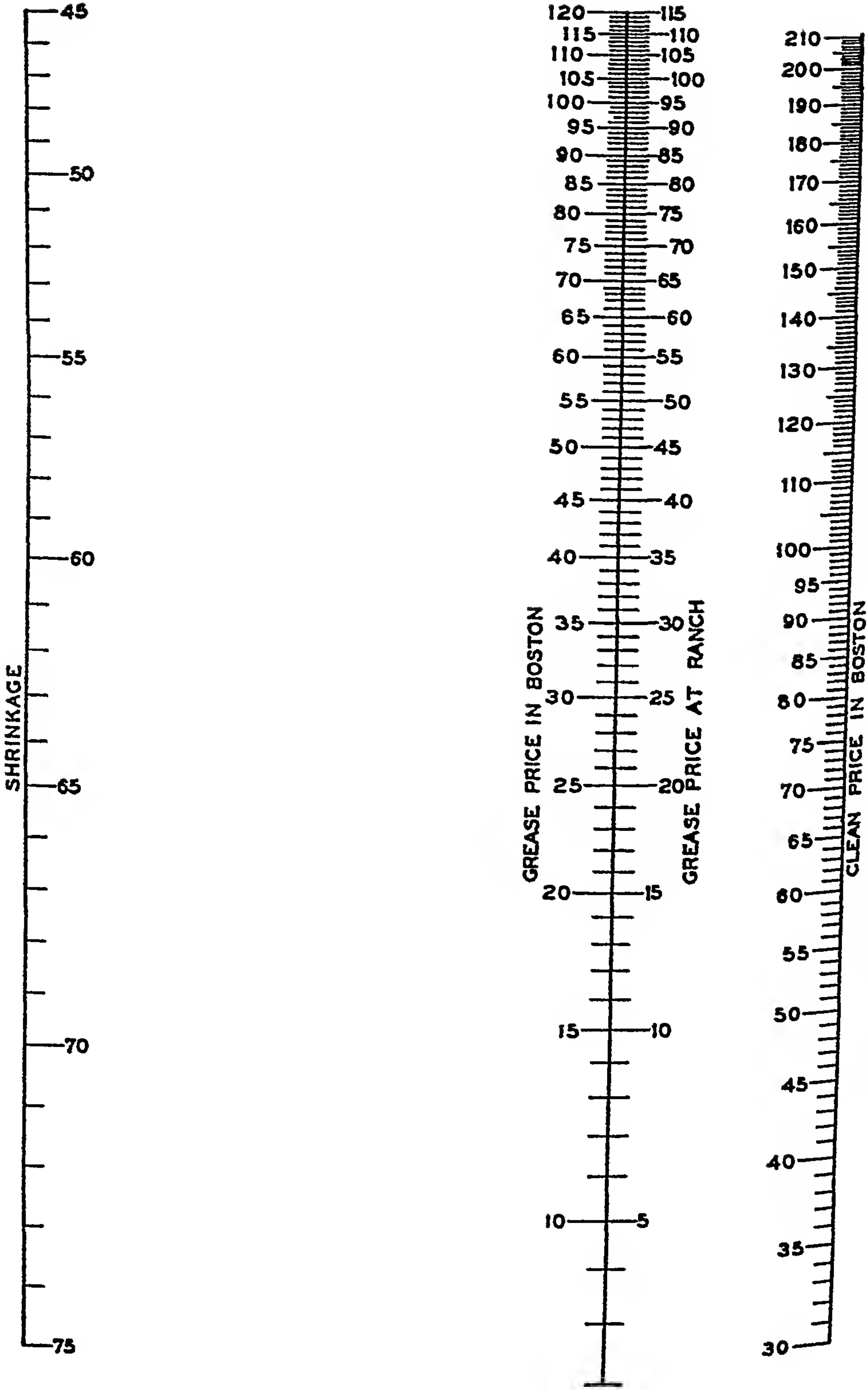


Fig 3 Price chart for calculation of wool prices (Courtesy S H Hunt)

THE PRODUCTION OF WOOL

Summary Survey of World Wool Production

Annual world production of wool averages around 4,000 million pounds, grease basis, of which about four-fifths is classified as "apparel" wool (merino and crossbred) and one-fifth as carpet wool

A summary survey of output by main groups of wool-producing countries is given in Table 5 As can be seen from these figures, the five main surplus countries of the Southern Hemisphere account for 70 per cent of total apparel wool output, and for well over one-half of world wool production The second main group of apparel

TABLE 5

WORLD WOOL PRODUCTION

(Summary survey by main groups of wool-producing countries, Average 1939–40—1943–44)

Groups of Wool-Producing Countries	*Millions of Pounds, Grease Basis*	*Per Cent of World Total*	*Group Percentages*
APPAREL WOOL PRODUCTION (MERINO AND CROSSBRED)			
			Per Cent of Apparel Wool Production
1 *Five Main Surplus Countries* (Australia, Argentina, New Zealand, South Africa, Uruguay)	2,277	57 1	70 2
2 *Five Main Deficit Countries* (United States, United Kingdom, France, Germany, Canada)	660	16 6	20 3
3 Rest of the World	307	7 7	9,5
Apparel wool production, total	3,244	81 4	100 0
CARPET WOOL PRODUCTION			
			Per Cent of Carpet Wool Production
1 *Three Main Carpet-Wool-Producing Countries* (U S S R., China, India)	465	11 7	62 8
2 Rest of the World	276	6 9	37.2
Carpet wool production, total	741	18 6	100 0
WORLD TOTAL	3,985	100 0	—

Source G Blau, *Wool in World Economy*, Part I

wool producers comprises the five main deficit countries—the United States, United Kingdom, Canada, France, and Germany—accounting together for 20 per cent of total apparel wool supplies The United States is by far the most important producer in this second group Indeed, the American domestic wool clip is the third largest in the world, ranking next in importance only to Australia and Argentina At the same time, the United States belongs to the class of deficit countries because her own output is not sufficient to meet domestic needs and considerable quantities of Dominion and South American wool must be imported. Together, the ten countries comprising the surplus and deficit groups account for 90 per cent of the world's apparel wool output, and 74 per cent of the world clip

The world's three main carpet-wool-producing countries are the U S S R, India, and China, which account for 63 per cent of total carpet wool output, and 12 per cent of total world wool output The Balkans, Turkey, Iran, French Africa, and some South American countries produce the bulk of the remaining 37 per cent of carpet-wool production, or 7 per cent of the total for all wools Carpet wools are largely home-consumed and represent less than 10 per cent of world exports.

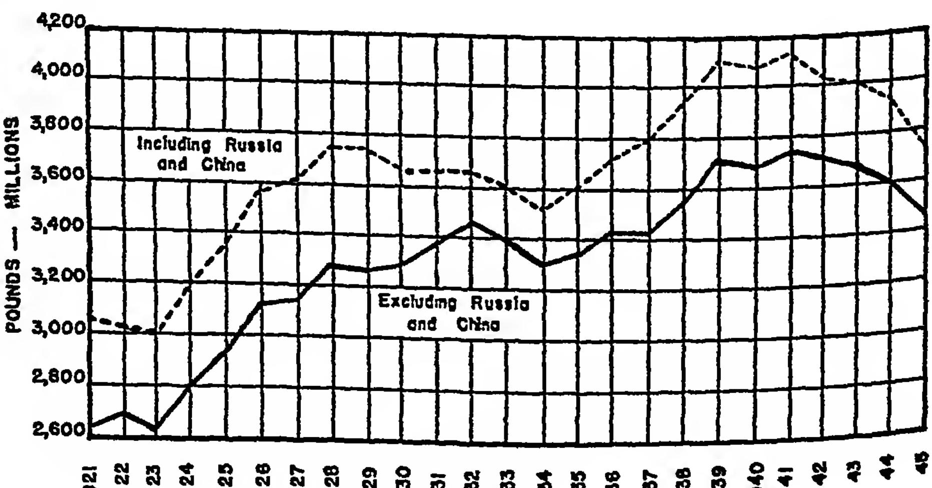


Fig 4 World wool production from 1921 to 1945
(*Courtesy U S Dept of Agriculture*)

The world wool production, which before World War I averaged just over 3,000 million pounds, was increased by 23 per cent above the 1909-13 level in 1934-38, and by 30 per cent in 1939-43 Output in the deficit countries' group in 1939-43 was only 11 per cent above the 1909-13 level; but the increase in world wool output during the interwar period was strongly influenced by the more than proportionate expansion of production in the surplus countries which represent more than half of world output

The deficit group's 11 per cent increase from 1909-13 to 1939-43 was mainly the result of the rise by one-third in the size of the American clip America's share in the deficit group's total rose from 58 per cent in 1909-13 to 70 per cent in 1939-43, and thus more than counterbalanced the downward output changes in some of the European countries

Despite occasional sharp changes in the size of individual countries' clips, short-term variations in wool supply by groups of countries are, on the whole, relatively small A survey of such year-to-year changes during the 35-year period from 1909-10 to 1943-44 shows that even in the surplus group, where year-to-year changes were relatively more marked than in the deficit group, only two out of thirty-four year-to-year changes exceeded 10 per cent of the previous year's total, whereas in twenty-four instances the changes were less than 5 per cent In the deficit group, twenty-nine out of thirty-four year-to-year changes were less than 5 per cent and none were more than 10 per cent

Dividing the total output of both groups into merino and crossbred sections, it is seen that year-to-year fluctuations in merino production were, on the whole, more marked than in crossbred This is partly owing to the more serious effects of drought in merino-producing areas The relatively greater stability in the crossbred section is caused by the influence of meat prices, which are more stable than wool prices and which tend to make the supply of crossbred wool even less responsive to changes in wool values than the supply of merino wool Year-to-year changes in the size of total world production over the period considered correspond to the pattern of the more stable "crossbred section" of apparel wool output

The two main components determining the trend of wool production are changes in sheep numbers and changes in the average yield per sheep The 1945 *Report* of the London Wool Conference gives estimates which appear to be based on the assumption that neither of these two components is likely to increase over the next

TABLE 6

WORLD WOOL PRODUCTION, GREASE BASIS, AND APPARENT CONSUMPTION
(In millions of pounds)

Country and Area	*Apparent Consumption 1934–38 Average*	*Production 1934–38 Average*	*1939–43 Average*	*1944*	*1945*
North and Central America					
United States	650 0	425 1	446 0	418 1	389.6
Canada	32 0	17 6	16 7	19 3	19 0
Others	8 0	11 6	11 2	14 2	14 2
Total	690 0	454 3	473 9	451.6	422 8
South America					
Argentina	59 0	370 4	487 8	500.0	500 0
Uruguay	4 0	117 8	130 0	142 0	137 0
Brazil	15 0	38 4	40.2	42 5	42 5
Chile	12 0	32 7	35 8	36 8	34 0
Peru	12 0	21 0	17 7	18 9	16 8
Others	(8 0)	14 2	13.5	10.1	10 1
Total	110 0	594 5	724 9	750.3	740 4
Europe, excluding Russia					
United Kingdom	661 0	108 1	98 2	86 8	90 0
Ireland	3 0	17 1	16 0	15.9	16 2
France	424 0	37 9	31 6	26 0	25 0
Germany	322 0	34 9	0 5	19 9	a
Belgium	122 0	0 8	—	—	—
Italy	124 0	37 8	41.1	27.6	23 0
Others	414 0	286 8	280 4	283 8	228 1
Total	2,070 0	523 4	517 8	490 0	430 1
Asia, excluding China					
Turkey	33 0	54 3	65 3	69.6	70 3
India	50 0	85 2	80.5	85 0	85 0
Japan	204 0	—	—	—	—
Others	(50 0)	74 5	74 4	88 5	98 6
Total	337 0	214 0	220 1	243 1	253 9
Africa					
British South Africa	—	238 6	257.3	234 0	228 0
French North Africa	(40 0)	84 3	91 6	107 0	90 7
Others	—	13 4	12 7	10 3	10 4
Total	(50 0)	336 3	361 6	351 3	329 1
Australia	98 0	995 3	1,125 9	990 0	905 0
New Zealand	7 0	299 3	327 9	373 0	370 0
Russia	270 0	210 0	294 0	210 0	210 0
China	40 0	78 0	90 0	90 0	90 0
Estimated World Total	3,672 0	3,704 0	4,136.0	3,949.3	3,751 3

Source U S Department of Agriculture, *Agricultural Statistics*, 1944, pp 322 323, *Bulletin*, National Association of Wool Manufacturers, Vol LXXV, 1945, pp 162-163

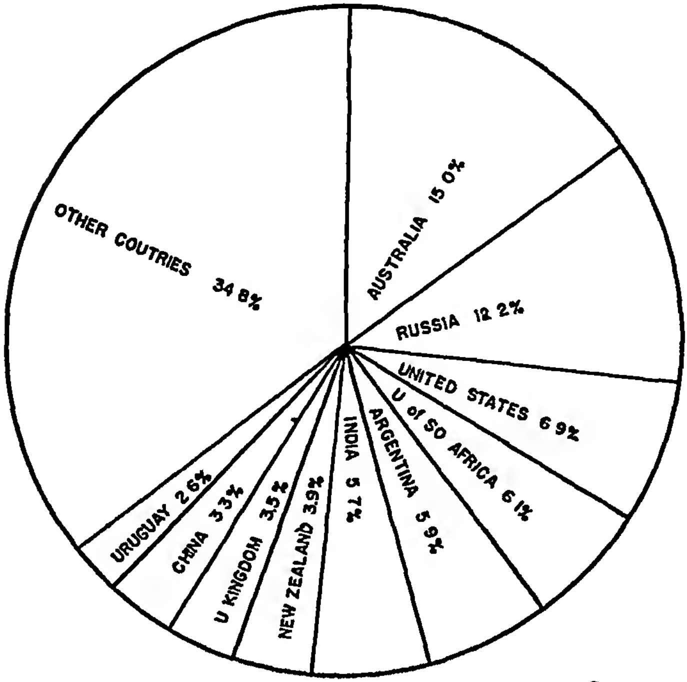


Fig 5 Number of sheep in world 717,350,000 head 1926-1935 average.

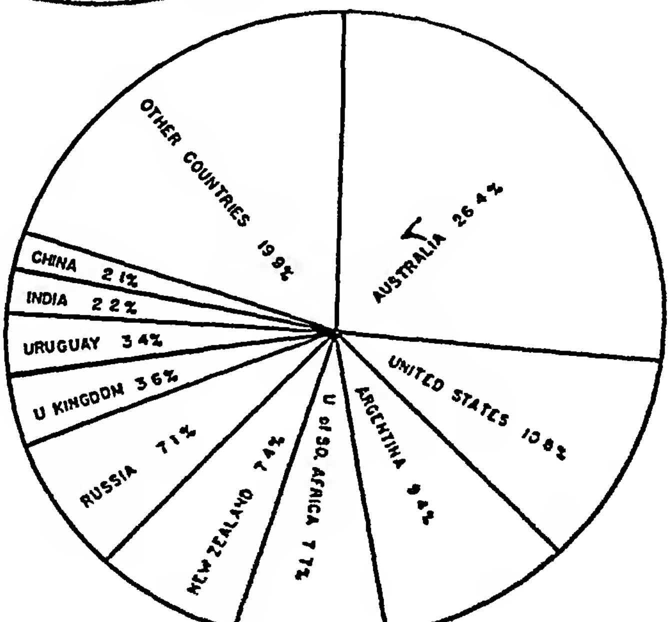


Fig 6 World wool production 3,667,-000,000 lbs 1926-1935 average.

decade, or that further increases in the average yield will be offset by a reduction in numbers.

Concerning sheep numbers, it is a view shared by many experts that the marked upward trend of the last 100 years is not likely to continue especially not in the principal merino areas. It is held that the optimum sheep-carrying capacity of grazing land has on the whole been reached, or, in some instances, surpassed.

Much more optimistic forecasts have been made, however, concerning the longer-term prospects of increasing the average yield per sheep. Dr Clunies Ross, a well-known expert in this field, holds the view that the great bulk of Australian sheep could produce 50 per cent more wool per head if adequately fed and that, as the wool-growing capacity of sheep is determined basically by heredity great advances could be made by the wide adoption of progeny testing of rams. Modern scientific research has led to important improvements in the application of this system. The "high-yield" breeds evolved in this way can only be maintained by improved nutrition based on more labor-intensive and capital-intensive methods of production.

TABLE 7

TEN LEADING COUNTRIES IN WORLD WOOL PRODUCTION
(In millions of pounds, grease basis)

Country	1934–38 Average	Per Cent	1939–43 Average	Per Cent	1944	Per Cent	1945	Per Cent
Australia	995.3	26.8	1,123.9	27.3	990.0	25.1	905.0	24.1
United States	425.1	11.4	446.0	10.8	418.1	10.5	389.6	10.4
Argentina	370.4	10.0	487.8	11.8	500.0	12.5	500.0	13.3
New Zealand	299.3	8.0	327.9	7.9	373.0	9.4	370.0	9.8
British South Africa	238.6	6.4	257.3	6.2	234.0	5.9	228.0	6.1
Russia (U.S.S.R.)	210.0	5.6	294.0	7.2	210.0	5.3	210.0	5.6
Uruguay	118.0	3.2	130.0	3.1	142.0	3.5	137.0	3.6
United Kingdom	108.1	2.9	98.2	2.4	86.8	2.9	90.0	2.4
China	90.0	2.4	90.0	2.2	90.0	2.3	90.0	2.4
India	85.2	2.3	80.5	1.9	85.0	2.1	85.0	2.3
Total	2,940.0	79.0	3,337.7	80.8	3,128.9	79.4	3,004.6	80.0
Estimated World Total	3,720.0	100.0	4,136.0	100.0	3,950.0	100.0	3,760.0	100.0

Source. U. S. Department of Agriculture, *Agricultural Statistics*, 1944, pp. 322-323, *Bulletin*, National Association of Wool Manufacturers, Vol LXXV, 1945, pp 162-163

Characteristics of the Main Wool Types.

Characteristics of merino wools. Merino wools are the most valuable wools produced in the world. Approximately 35 per cent

of the world's wool production in 1938 came under the merino classification Of this, 57 per cent was produced in Australia, according to an estimate by the Australian government

The merino wools are noted for their softness, fineness, strength, and elasticity and are especially desired for their superior spinning and felting properties. For spinning the finest woolen and worsted yarns, merino wools are an absolute necessity Flannels and knit goods of high quality, suiting and dress goods of fine texture, face-finished fabrics such as broadcloths, billiard cloths, doeskins, meltons, and various uniform cloths are dependent on merino stock No other wool would give the required appearance, handle, finish, and character which distinguishes each of these fabrics, and in many cases no other wool could be spun to the required fine yarn sizes

The bulk of the merino wools grade 64s and up, but some of the Australian strong wool merinos produce wools as low as 58s The

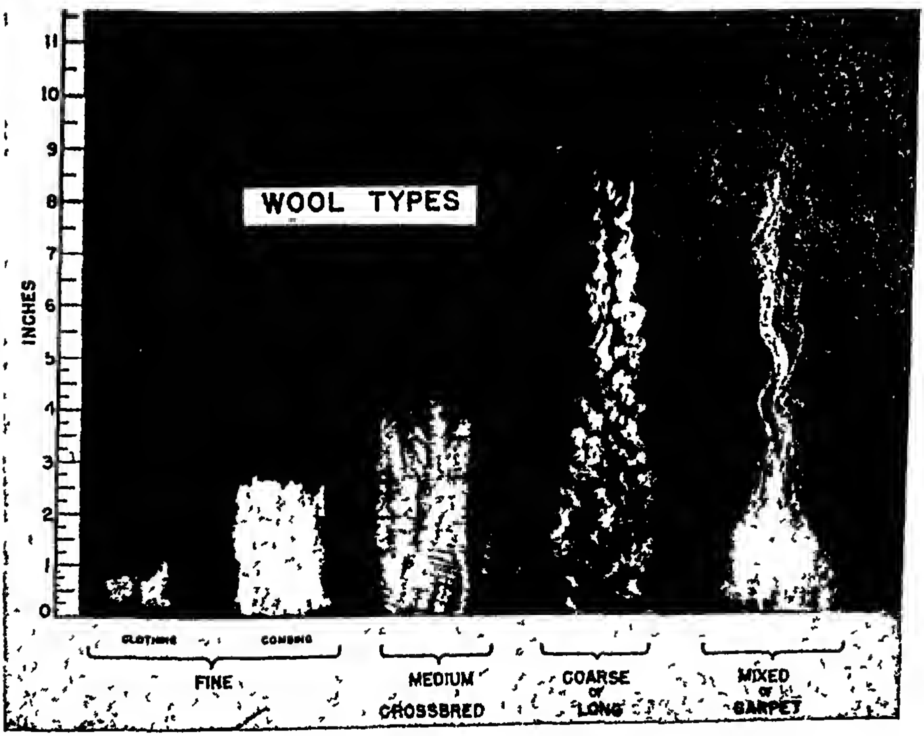


Fig 7 Variation of fiber length in different types of wools

fleeces are generally heavy, 10 pounds and up, and very greasy. They shrink from 40 to 70 per cent, depending on the origin of the wool The fibers may range in length from 1 to 5 inches.

Characteristics of medium wools The fleece of medium wool occupies a middle position between the high fineness and density of the merino wools and the length and coarseness of the long wools There is no clear-cut borderline between fine and medium wools The main criterion for the classification is the fineness of the fibers, which ranges from low quarter-blood to half-blood, respectively from 46s to 60s

The fibers may range in length from 2 to 5 inches generally they are of good combing length The fleeces are considerably lighter than merino fleeces, and because of their openness they contain less sand and are less greasy In scouring, the shrinkage ranges between 40 and 60 per cent, depending on the grade and the origin of the wool The relationships between grade shrinkage, and length are given in Table 8

TABLE 8

RELATIONSHIP BETWEEN GRADE, SHRINKAGE, AND LENGTH OF UNITED STATES WOOLS

Grades	*Shrinkage, Domestic (per cent)*	*Shrinkage, Territory (per cent)*	*Approximate Length (inches)*
Fine	62	66	1½ to 3
Half-blood	56	60	—
Three-eighths blood	47	57	2 to 4
Quarter-blood	43	52	3 to 5
Low	42	46	3½ to 6

As the ability to felt decreases with the increase in the diameter of the fibers, the medium wools (especially the down wools) are very suitable for hosiery and knit goods, whether machine- or hand-knitted The standard wool grade for hand-knitting yarn is 52s-54s The medium wools are also extensively used for ladies' wear fabrics such as suitings, coatings, and fine tweeds, and for men's medium worsted suitings, serges, flannels, overcoatings, and blankets

Characteristics of long wools In the pedigree diagram of the domestic sheep, two classes of breeds are listed as yielding long wools, namely, the breeds growing demiluster wools and the breeds

growing luster wools. The breeds growing demiluster wools originated from various crosses of luster and down sheep and of luster and English mountain sheep Because of this foundation the fineness of the demiluster wools overlaps that of the medium wools The fineness range is from 44s or common to 50s or quarter-blood, the lengths range from 6 to 9 inches The wool is of a lustrous nature and is manufactured into plain cloths, tweeds, serges, overcoatings, blankets, and felts

The true long wools are the luster wools derived from the Lincoln, Leicester, and Cotswold sheep (See Table 7, Chapter 2) The standard is set by the Lincoln wool, which has a worldwide reputation for its length of staple and beautiful luster The luster wools are the coarsest wools grown, ranging in fiber diameter from below 36s or braid to 44s or common They also hold the length record with 32 inch staple from yearling Lincoln ewes Normally, the wool grows from 8 to 15 inches Whereas the wool of the Lincoln and Leicester forms broad locks, that of the Cotswold forms curly locks, resembling mohair. All long wools are light shrinking, losing from 20 to 35 per cent in weight through scouring The luster wools are manufactured into braids, buntings, shoe laces, linings, lustrous worsted fabrics, and pulp felts

Characteristics of crossbred wools In respect to fineness, crossbred wools belong to the medium type, but they have the added value of being 1 to 3 inches longer, and the amount of wool produced per sheep is from 75 to 100 per cent higher than that of the down breeds Table 9 shows the comparison of the wool produced by the crossbred breeds and two down breeds in Australia

TABLE 9

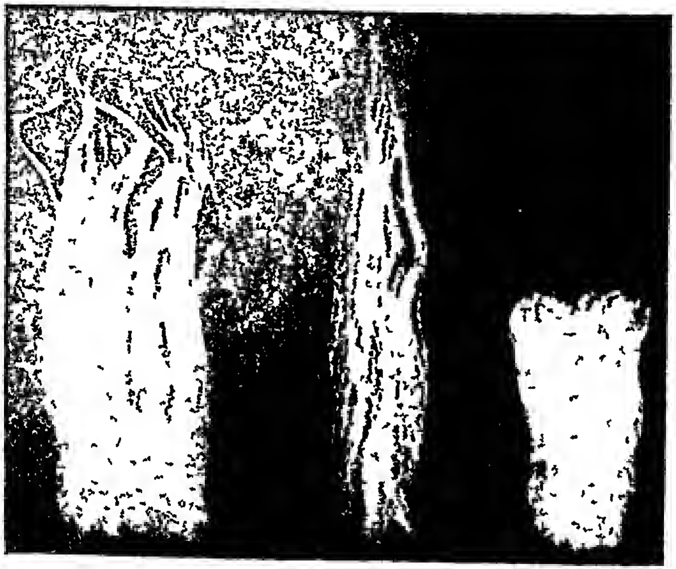
COMPARISON OF AUSTRALIAN CROSSBRED AND DOWN WOOLS

Breeds	*Length (inches)*	*Weight of Fleece (pounds)*	*Grade*	*Yield (per cent)*	*Noil Yield (per cent)*
Polwarth	5½	8 to 9	56s to 64s	60 to 66	4 to 6
Corriedale	5½	10	50s to 56s	64 to 68	5 to 7
Southdown	2½	3 to 4	54s to 56s	60 to 65	12
Shropshire	3½	6	50s to 56s	60 to 65	12

In addition, Table 9 shows that because of the longer staple of the crossbred wools the yield of noils in combing is only half that of the down wool, which increases their value still further.

Some of these wools, especially the ones collected at Punta Arenas, on the southern tip of South America, are noted in the hosiery trade for their good color and springiness, which is accompanied by a full and lofty handle The crossbred wool is used mainly in the knitting trade, but it is also very suitable for all types of worsted fabrics, for ladies' as well as men's wear, such as serges and tweeds. It is also very desirable in the manufacture of medium class of felts

During World War II, large amounts of crossbred wools were used by the carpet industry as a substitute for carpet wools



A B C

Fig 8 (A) A lock of Navajo wool separated to show (B) long coarse outer coat fibers and (C) undercoat fibers

(Courtesy U. S Department of Agriculture)

Characteristics of carpet wools. The carpet wool fleeces are composed of a mixture of long, hairy fibers forming the outer coat and a fine undercoat of true wool. These two types of fibers make up the main part of the carpet wool fleece, but a third type of fiber, the so-called kemp, also occurs in varying amounts.

The average fineness range for the coarse, long, hairy fibers is from 30 to 40 microns or from 50s down to 36s, whereas the undercoat measures as fine as 16 microns and up to 24 microns, which covers a grade range from 100s down to 60s The coarse fibers may range in length from 4 to 10 inches and the fine fibers from 2 to 6 inches. On a weight basis, the long fibers generally make up from 20 to 40 per cent of the staple. The amount of kemp present can vary from 1 to 20 per cent This is a brittle, opaque fiber, which is easily identified. All degrees of variation between these three types

of fibers are found, and when these wools are analyzed microscopically, several subtypes of fibers have been distinguished under each type

Burns, Johnston and Chem describe the various fiber types as follows:

Carpet fiber types Chinese and other carpet wools of mixed wool type consist of different varieties of fiber such as true wool (fine undercoat), kemps (usually lying loose in the fleece), heterotypical fibers (hair and intermediate fibers), and colored fibers

True wool refers to those fibers that make up the fine undercoat of the mixed-wool sheep Those fibers are oval in cross-section, have a solid cortical mass making up the shaft of the fiber, show no medullation, and are usually quite fine Even in fleeces of coarse appearance these true wool fibers of the undercoat may be of 64's to 70's spinning quality

Kemps, which lie loose in the fleece, are easily distinguished from the longer, coarse medullated fibers, which are not normally shed

Heterotypical fibers Heterotypical fibers, as the name implies, are neither wool nor kemp Originally the name was applied to those fibers which within the same fiber shaft showed the characteristics of wool fibers, kemps, and hairs Later, as the kemps were subdivided, the name came to be applied to those fibers which showed the fiber shaft characteristics of both wool and hair in the same fiber, particularly in respect to medullation and nonmedullation The structure of heterotypical fibers may vary considerably from the proximal to the distal end

Colored fibers range from pale yellow to black in the true wool; in the kemps, from black to red or fawn and on to yellow or buff A great amount of variation in color exists, even in the same fiber

As the name indicates, carpet wools are principally used in the manufacture of carpets and rugs Wools from different geographical areas have certain definite quality characteristic of value in floor covering In general, wools from the East India region furnish characteristics of loftiness and coverage to the pile yarn, resist crushing and matting, and show high relative wear value Some New Zealand types have the highest resistance to abrasive wear but other types are smooth and contribute to shedding or fluffing China wools are excellent spinning wools but show relatively lower abrasive wear resistance than other types Some types of South American wools furnish high luster but contribute to a thin yarn and shedding or fluffing The whiteness of South American and New Zealand types make them especially desirable for very light colors

At times when wools of the other classes are high in price, cloth manufacturers turn to the better carpet wools for relief; but these wools do not give the same results as those they replace Some of the better grades of carpet wools are mixed with other wools in the manufacture of coarse fabrics, such as the cheaper grades of cloakings, overcoatings, coarse tweeds, and cheviots. Some grades are also used for felt boots, horse blankets, coarse upholstery goods, robes, paper makers' felts, and wadding for gun cartridges. A large source of supply for carpet wools, other than those produced by unimproved native sheep, are the skirtings, britch, badly cotted fleeces, tags, and pieces from coarse domestic and crossbred wools Carpet wools are comparatively coarse and are usually graded as coarse, medium, and good

Australian Wools

The Commonwealth of Australia, both in number of sheep and quantity and value of wool produced, is the premier country of the world Australia covers an area of nearly 3,000,000 square miles Roughly 1,000,000 square miles have an annual rainfall of over 20 inches, 1,000,000 square miles from 10 to 20 inches, and 1,000,000 under 10 inches In the area having a rainfall between 10 and 20 inches, the bulk of Australian wool is produced

The seven states making up the Commonwealth of Australia are Tasmania, Victoria, New South Wales, Queensland, South Australia, West Australia, the Northern Territory, and Federal Capital Territory With the exception of the Northern Territory, all the states share in the wool production (See the map, Fig 9)

Wool production in the Commonwealth during 1944-45 showed a decline from the record output of the previous season This was due mainly to the severe drought losses of sheep and lambs and to the adverse effect of the dry conditions on the growth of wool The Commonwealth production reached a total of 3,175,618 bales, compared with the record figure of 3,708,212 bales in 1943-44. As the weight of bales is a varying quantity, it becomes necessary to make a comparison also in total weight On this basis the Commonwealth production was 947,860,944 pounds compared with 1,132,615,077 pounds in 1943-44 and 1,120,048,224 pounds in 1942-43 The average weight per bale, influenced by the lighter fleeces in 1944-45, was only 298 pounds, as compared with 305 pounds in 1943-44 and 312 pounds in 1942-43

In Table 10 are compiled the number of sheep and the wool production of the states of the Commonwealth for the seasons 1943-44 and 1944-45.

TABLE 10

AUSTRALIAN SHEEP AND WOOL PRODUCTION BY STATES

State	Sheep Number 1943–44	Sheep Number 1944–45	Number of Bales 1943–44	Number of Bales 1944–45	Pounds per Bale 1943–44	Pounds per Bale 1944–45
New South Wales	56,837,300	46,662,000	1,736,000	1,470,000	307	296
Queensland	23,255,584	21,267,602	646,500	543,373	307	306
Victoria	19,220,457	16,457,101	580,712	496,745	287	287
South Australia	10,359,669	8,473,939	362,000	336,500	318	312
West Australia	11,130,000	10,020,299	325,000	270,000	320	302
Tasmania	2,226,907	2,187,799	64,500	59,000	279	283
Average	—	—	—	—	305	298

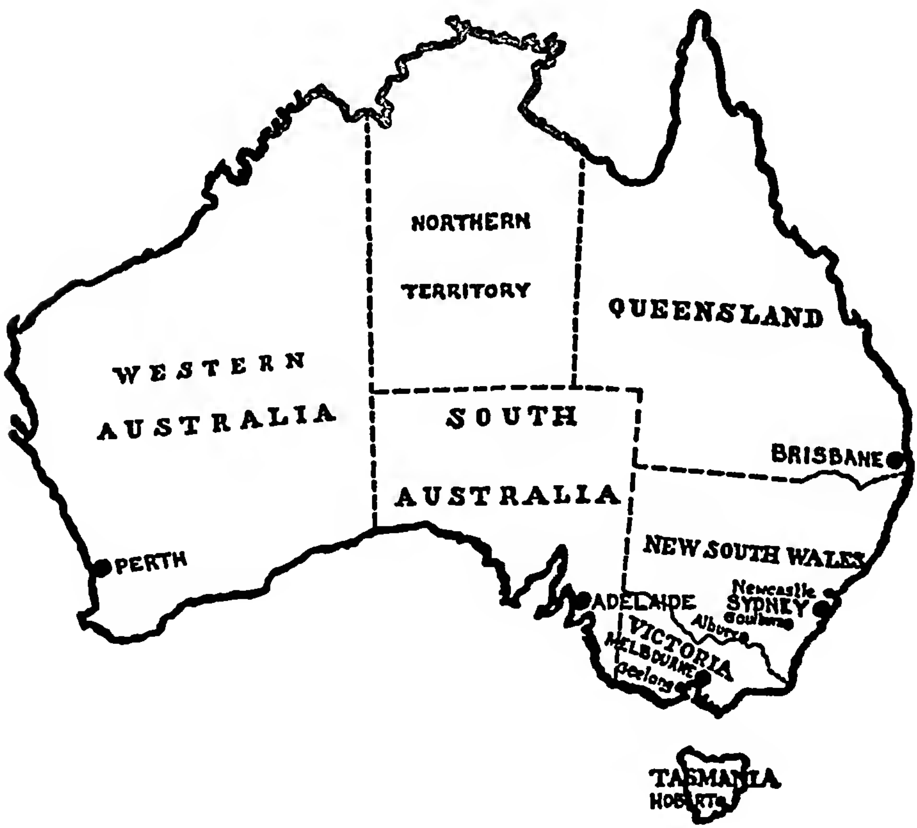


Fig 9 Commonwealth of Australia the seven states

The leading wool centers in each state are. New South Wales: Sydney, Newcastle, Goulburn, and Albury, Victoria. Melbourne and Geelong, South Australia Adelaide, West Australia · Perth, Queensland: Brisbane, Tasmania Launceston and Hobart.

The importance of these centers is clearly seen from Table 11 which gives the average number of bales sold and appraised from 1914 to 1945

TABLE 11

WOOL SOLD OR APPRAISED IN AUSTRALIAN CENTERS
(In thousands of bales)

Average	*1914–18 5 Seasons*	*1919–28 10 Seasons*	*1929–38 10 Seasons*	*1939–43 5 Seasons*	*1944–45*
Sydney	695	859	1,189	1,367	1,159
Melbourne	346	387	482	641	550
Geelong	116	143	193	240	215
Adelaide	143	201	246	371	334
Perth	60	106	175	267	270
Brisbane	264	319	463	631	533
Tasmania	30	37	45	63	59

Source Dalgaty's *Annual Wool Review for Australia and New Zealand*, 1944 45, p 17.

The wool sold during the five-year period from 1934-39 consisted of 84 per cent merino and 16 per cent crossbred During the war years, with the increased demand for crossbred wool for military purposes and a better return from the dual sheep, the production followed this demand and in the 1944-45 season the amount of crossbred wools had increased to 24 per cent, or fully 8 per cent above the prewar figure. Respectively, the amount of merino wool had dropped to 76 per cent

The bulk of the merino wool is a bold well-grown 64s of medium spinning quality, showing good length of staple, and reflecting breeding characteristics of constitution, backed by ideal climatic and pasture conditions In Australia, also, finer counts up to 100s, are to be found in certain markets, whereas in other centers strong merino or 60s may be had showing good length of staple and body.

In the crossbred section some fine types are displayed, from choicest style three-eighths blood to "braid" Approximately 93 per cent of Australian wool sold at auction is greasy, the balance, 7 per cent, being scoured. Also 95 per cent of the total represents wool from grown sheep, 5 per cent being lamb's wool

TABLE 12

CLASSIFICATION OF AUSTRALIAN WOOL OF A YEAR'S NORMAL PRODUCTION AS PERCENTAGE OF TOTAL

NOBLE COMBING

	70s and over	*60s–64s to 64s–70s*	*58s–60s*	*50s–56s*	*50s and under*	*Total*
Spinners' fleece						
Free or practically free	1.0	5.0	1.3	0.7	0.1	8.1
Good topmaking fleece						
Light burr	2.1	20.5	6.3	3.2	0.6	32.7
Heavy burr	(a)	0.7	0.2	0.1	0.1	1.1
Average topmaking fleece						
Light burr	0.2	5.3	2.6	0.6	0.1	8.8
Heavy burr	(a)	0.6	0.5	0.2	(a)	1.3
Super pieces, free or light burr	(a)	1.1	0.2	0.1	(a)	1.4
Average pieces						
Light burr	0.2	6.3	2.9	0.8	0.1	10.4
Heavy burr	(a)	2.3	1.1	0.2	(a)	3.6
Total	3.5	41.8	15.1	5.9	1.0	67.4

FRENCH COMBING

	70s and over	*60s–64s to 64s–70s*	*58s–60s*	*50s–56s*	*50s and under*	*Total*
Fleece						
Light burr	0.8	2.2	0.1	—	—	3.1
Heavy burr	(a)	0.1	(a)	—	—	0.1
Pieces						
Light burr	0.3	6.2	1.6	0.6	0.1	8.8
Heavy burr	(a)	3.2	0.6	0.2	(a)	4.0
Total	1.1	11.7	2.3	0.8	0.1	16.0

CARDING WOOLS

	60s and over	*Comeback and Fine Crossbred*	*Medium and Coarse Crossbred*	*Total*
Fleece and pieces				
Free	0.7	(a)	—	0.7
Odd burr	0.2	(a)	—	0.2
Carbonizing	2.3	0.7	(a)	3.0
Lambs				
Free	0.3	0.1	(a)	0.4
Odd burr	0.5	0.4	(a)	0.9
Carbonizing	0.9	0.9	0.1	1.9
Locks and crutchings				
Free	0.1	(a)	(a)	0.1
Odd burr	1.5	0.5	(a)	2.0
Carbonizing	4.6	2.5	0.1	7.2
Total	11.1	5.2(b)	0.3(b)	16.6

SUMMARY

	Bales	*Per Cent of Clip*
Noble combing	2,024,796	67.4
French combing	480,767	16.0
Carding wools	499,964	16.6
GRAND TOTAL	3,005,527	100.0

(a) Negligible—less than 0.1 per cent (b) Including negligible percentages

The Australian Wool Realization Commission has made available a broad classification of the Australian wool clip based on a single year of normal production by a dissection of the appraisement records of the Central Wool Committee. This classification is shown in Table 12

New South Wales has a world wide reputation for fine merino wools, bulk 70s In prewar times 90 per cent of the clip was merino, but, during the war, this dropped to 83 per cent The best merino wools, 80s and 70s, are grown in Yass, Mudgee, East Riviera, and New England districts, which are all at an altitude of 1000 to 2000 feet These wools are known for their length, fineness, pliability, and soft texture with brightness The type is unequaled by any other grown outside of Australia From the districts of Central Riverina, Boonoke, Wanganella, and Dubbo, merino wool of the medium class, 64s to 70s, is obtained This class of wool is produced by the greatest majority of sheep and comprises fully one-half of this state's flocks It is an all around type for either spinning or combing Of the fine crossbreeds grown in New South Wales, foremost in reputation are the Corriedale and the Polwarth. Coarser wools also are produced from Lincoln-merino, and other luster-merino crosses These wools vary from 36s up to 58s quality, and in length from 12 inches to 5 inches Short fine 58s wool is esteemed by the knitting industry

Victorian wools include some of the best merino wools produced in the Commonwealth, and they are known as Port Phillip They are well known for their good staple and uniformity of fiber The crossbreeds are mostly derived from Lincoln, Border Leicester, and Romney Marsh crossings All conditions favor the grades of crossbred wools for which the southern state is favorably recognized In prewar times the clip was 59 per cent merino and at present the clip is 43 per cent merino

Queensland, being a semitropical country, is not as suitable for crossbreeds as it is for merino wool growing, in prewar times it produced 100 per cent merino wools and at present the figure given is 99 per cent The bulk of the wools is not as well known as those of the southern states and resembles to a certain degree fine Texas wools, with the bulk 64s-70s quality Queensland wools are known for their whiteness after scouring and are very serviceable in the worsted and woolen trades

The red wools of West Australia are so called because of the sands which adhere to the grease on the wool Of late years, this wool has been of a regular type, medium quality, and combing length but is

more fit for weft than for warp Improvements have been made through the introduction of the Boonoke, Wanganella, and Bundemar strains But because of the dry and sandy character of the wools, these improvements have been limited In prewar times, 95 per cent of the clip was merino, the 1944-45 clip was reported as consisting of 92 per cent merino

South Australia at present is producing a bulk of warp wools, 60s-64s quality They favor the breeding of sheep with big, plain, large bodies, producing a lengthy staple of excellent color which is especially suited to the topographical condition of this country of many open and exposed hot plains The prewar percentage of merino was 94 per cent, the present listing is 89 per cent The merino wools are fairly heavy in grease and yolk These two substances are partly responsible for foreign matters clinging to the wool and giving it an appearance which often indicates the district in which it was grown

Tasmania may be given the title of the "Merino Stud Farm of the World" because it has played the foremost part in building up the merino stud sheep Even though the percentage of merino wool grown is so low, the wool produced is of the most excellent quality and of rather heavy condition Approximately 300 bales are available of quality 90 and above Being of such high fineness, there is a larger proportion of superior clothing in this state than in any other In prewar times the clip was 23 per cent merino It varied during the war from a low of 23 per cent up to a high of 34 per cent for the 1943-44 season For 1944-45 it is listed as 24 per cent

The Federal Territory is the only state where the wool production is not officially listed because of the small amount that is produced

New Zealand Wools

New Zealand is the largest mutton-producing country in the world and therefore the greatest supplier of crossbred wools Of the 300,000,000 pounds of wool produced annually in New Zealand, only 3 per cent is derived from merino sheep The main breeds of sheep in New Zealand, as recorded by Hind, are shown in Table 13

The Wool Metrology Laboratory in the Canterbury Agricultural College made analyses of the 795,153 bales of grease wool produced in the 1943-44 season in New Zealand The fineness distribution of these bales was found to be as shown in Table 14

TABLE 13

BREEDS OF SHEEP IN NEW ZEALAND

Type	*Percentage*	*Type*	*Percentage*
Crossbred*	75.00	Merino	3.25
Romney	10.50	Luster	0.75
Southdown	6.25	Shropshire and Ryeland	0.25
Corriedale	4.00		

* Mostly Romney blood

TABLE 14

COUNT DISTRIBUTION OF TOTAL GREASY CLIP

Count	*Number of Bales*	*Percentages*
70	24	—
64	5,055	0.6
60	21,964	2.8
58	40,724	5.1
56	73,269	9.2
54	6,320	0.8
52	36,012	4.5
50	332,928	41.9
48	145,666	18.3
46	109,754	13.8
44	18,801	2.4
40	3,899	0.5
36	737	—
Total	795,153	99.9

These figures clearly demonstrate the nature of New Zealand wool production. Wools of 50s count and lower comprises 76.9 per cent of the total production. Of the remainder, only 3.4 per cent is of 60s count or higher. The average estimated yields vary from a low of 52 per cent for 64s to a high of 76 per cent for 44s.

Cape Merino or South African Wools

These wools are grown in the following four South African states: Cape Province (48 per cent), Orange Free State (34 per cent), Transvaal (12 per cent), and Natal (5 per cent). The main concentration and shipping points are East London, Durban, Port Elizabeth, and Capetown.

Some wools are shorn after about six or nine months of growth, hence the staple is short and can only be classed as "clothing" wool About 60 per cent of a twelve-month clip has a length of 2 to 2½ inches. The bulk of the wool is classed as 64s to 70s, with a considerable quantity of 80s Although the South African clip is finer than some of the Australian wool, it lacks the staple found in the Australian product Cape and Orange Free State wools vary in shrinkage from 50 to 60 per cent The area around Port Elizabeth is noted for its "snow white capes"

Transvaal wool shrinks between 48 and 53 per cent, whereas some of the Natal wool shrinks less than 40 per cent. The wool is eagerly sought, because of its suitability in the manufacture of woolen-spun uniform cloths, such as flannels, meltons, and kerseys. Generally excellent felting wools, some Cape wools are said to be inelastic and some nonfelting

South American Wools

The chief wool-producing areas of South America are in Argentina, which produces two-thirds (70 per cent in 1942) of the South American wools, Uruguay grows about a fifth (16 per cent in 1942), and Chile, Brazil, Peru, and the Falkland Islands yield the remainder

Buenos Aires, Montevideo, and Punta Arenas are stations for the collection and dispatch of the wool to the manufacturing countries Most of the Argentine clip is collected at Buenos Aires, the wools grown in Uruguay and southern Brazil are gathered at Montevideo, and wools from Patagonia and Tierra Del Fuego are shipped from Punta Arenas, the Chilean port on the Straits of Magellan South American wools often are known by the initials of the ports of shipment, the Buenos Aires wools are classed as "B A," Montevideo wools as "M V," and the Punta Arenas wools are known as "Punta wools" or "P.A"

Argentina merino wools The percentage of merino wool in the

TABLE 15

FINENESS OF ARGENTINE WOOL CLIP

	Per Cent
Fine wool	10
Fine crossbred wool	35
Medium crossbred wool	20
Low crossbred wool	30
Criolla wool (carpet wool)	5

Argentine wool clip is about 10 per cent (Table 15). According to Link, of the seventeen main breeds, amounting to 153,960 sheep in 1936, the merinos were represented by 17,809 Argentine merinos and 5018 Australian merinos

Argentina may be divided into three parts, the Andes area of the north, the Pampas area and the Parana River basin, and Patagonia in the south Crossbred wools are grown on sheep in the valleys where good pastures allow dual purpose sheep Merino sheep are kept on the high grounds of the Andes and in the Patagonia regions

The finest merino wools of South America come from Patagonia and are known by the names of the states—Chubut, Rio Negro, and Santa Cruz The Chubut wool quality is about 64s to 70s, but the wool is rather dry, resembling somewhat Brisbane wools The wool is excellent for French spinning The shrinkage varies between 55 and 65 per cent A serious defect of the wool grown from the Argentine merino is the presence of "kemp"

Uruguay merino wools As in Argentina, only a small percentage of the Montevideo wools is of the merino type; the largest percentage is crossbred wool of the finer grades 50s and up

United States Wools

The American wools are divided into two classes domestic and territory wools But neither of these terms is generally applied to Texas and California wools, which are separately designated

Domestic wools In general, domestic wools are all wools grown in the United States, as contrasted with foreign wools In the domestic woolen trade the term "domestic" is applied to wools grown east of the Rocky Mountains and Texas, exclusive of the western (range) portions of the Dakotas, Nebraska, and Kansas Most of these wools are known in the trade as fleece wools As the states in which they are grown are classified as farm states, in government statistics the term "farm-grown wools" is applied That term also includes the wool grown in the Willamette Valley of western Oregon and in parts of western Washington, as it is essentially farm grown

The principal states growing domestic merino wools are Ohio, Pennsylvania, West Virginia, New York, Michigan, Vermont, and Indiana The most important section is the Ohio River Valley; it comprises Ohio, southwestern Pennsylvania, and the eastern part of West Virginia

These fine wools compare favorably with any in the world and are equal to the fine Australian They are unusually sound and strong and are the most valuable American wools The domestic wools are, as a rule, almost free from burrs and dirt Special attention is given to breeding, the sheep being housed and given every possible attention The length of domestic merino wools ranges from 2 to 5 inches Merino wools from the Ohio Valley that are 3 inches and over are known as "delaine" wools They are obtained by careful selection in breeding combined with excellent feeding

Territory wools "Territory" wools, also known as western or range wools, are those grown in the states of Montana, Wyoming, Idaho, Nevada, Utah, Arizona, New Mexico, and Colorado, also the western portions of the Dakotas, Nebraska, and Kansas Territory includes most of the wools produced in Washington and Oregon but does not include wools of Texas and California The name "territory" dates back to the time when the regions west of the Missouri River, previous to their admittance to statehood, were called the territories

The name "territory" is not strictly adhered to, as many of the territory wools are called by the name of their state, when sold in bulk lots The production of Texas and California wool is included in government compilations under the term "range wools"

The sheep roaming in these western states seldom receive any housing or protection from winter storms and blizzards, and they are rarely furnished with fodder Tenacious burrs abounding in the greater part of the ranges become entangled in the fleeces The soil in most of the western ranges is sandy and alkaline The nature of the soil, sickness due to insufficient nourishment at various times, and exposure may weaken the wool in the fleeces of these sheep Therefore, at their best, the territory wools are seldom equal to similar domestic wools Most of these territory wools range from 1½ to 3 inches in length Because of excessive exposure to the elements, the wool generally feels quite harsh The wool varies slightly in its characteristics from one state to another, and an expert wool buyer seldom errs, when judging the fleece, as to the state in which the wool was grown However, the wools grade into one another almost imperceptibly Montana, Wyoming, and Idaho produce the best of the territory wools They are of about equal value and are usually grouped together in the market quotation for wool in the trade papers Wyoming wools are noted for their whiteness when scoured, and sought for the production of knitting yarns

Texas and California wools. These two wools, though grown far apart are usually grouped together Quite a high percentage of the sheep are sheared twice a year According to the season shorn, the fleeces are known as "spring" or "fall" Texas or California; or, based on the number of months on the sheep's back, they are designated as six-month, eight-month, and twelve-month wools

Today Texas produces over 20 per cent of the total wool clip in the United States, and 95 per cent is 64s or finer Texas is probably the only state in the Union where 80s wools are produced in large amounts Especially in the last few years some Texas ranches produced wool which compares favorably with the best Ohio wools or even some of the Australian wools The only setback is that they do not have the length The custom of shearing twice a year is reflected in the unevenness in lengths of most of the Texas wools. The length varies from half an inch to 1½ inches for six- and eight-month wools, and from 2 to 3½ inches for twelve-month wools. Many of them are deficient in color.

California wools According to Wilson, the California clip as a whole is predominantly a fine wool clip Parts of northern California produce some of the best wools in the United States, whereas the wool from the central and southern parts of California is short and defective Generally, California wools do not command the prices brought by Texas and territory wools, because most of them are liable to contain more injurious vegetable matter than wools of the territory states

The U S Tariff Commission, in surveying the war-time supply situation, made a study of United States production of shorn and pulled wools, by grades, their estimated clean scoured yields, and production on the scoured basis This study covers the five-year period 1936-40, when conditions of production were approximately normal

Shorn and pulled wools produced Table 16 shows the United States production of shorn and pulled wools as estimated by the U S Department of Agriculture for the period 1931-45 In 1936-40, when conditions of production were approximately normal, the shorn wools averaged 362,000,000 pounds and pulled wools 65,000,000 pounds per year.

The percentages of production of farm- and range-shorn wools and of all pulled wools by grades are combined in the total production figure in Table 17 The yield of each type grown is shown

in Table 17 and is used to give total figures for clean scoured wool produced In 1936-40, the average annual production of farm-shorn

TABLE 16

RAW WOOL UNITED STATES PRODUCTION, 1931–45, IN MILLIONS OF POUNDS

Year	*Shorn*	*Pulled*	*Total*
1931	376 3	66 1	442 4
1932	351 0	67 1	418 1
1933	374 2	64 2	438 4
1934	368 9	60 5	429 4
1935	361 5	66 0	427 5
Average, 1931–35	366 3	64 8	431 1
1936	352 9	66 2	419 1
1937	357 5	66 2	423 7
1938	361 2	64 5	425 7
1939	363 7	64 5	428 2
1940	374 6	62 0	436 6
Average, 1936–40	362 0	64 7	426 7
1941	390 6	65 8	456 4
1942	392 4	66 7	459 1
1943	384 4	65 2	449 6
1944	347 1	71 0	418 1
1945	321 0	66 0	387 0
Average, 1941–45	367 1	66 9	434 0

Source Estimates of U S Department of Agriculture

wools was 91,000,000 pounds, as compared with 282,000,000 pounds of range wools Because of relatively high scoured yields, averaging 51 per cent, the farm-grown wools had a scoured weight of 47,200,000 pounds, the range wools, with an average scoured yield of 31 per cent, had a scoured weight of 104,100,000 pounds Thus, although the weight of the range wools, as shown, was three times that of the farm wools, on the scoured basis the volume of the former was only about 2¼ times as great as that of the latter The 65,000,000 pounds of pulled wools, with an average yield of 73 per cent, had a scoured weight of 47,600,000 pounds The total annual production of 438,000,000 pounds of shorn and pulled wools, with an average yield of about 45 5 per cent, had a scoured weight of 198,900,000 pounds

About 9 per cent of the wools shorn in the farming region are half-bloods, as compared with 18 per cent in the range region In some of the more favorable range areas, particularly when lush summer feed is available for the production of fat market lambs, the larger crossbred ewes, which produce half-blood wool, are preferred to fine-wool ewes In the farming states, where conditions of production favor larger sheep and more emphasis on market lambs, most sheep raisers make a clean break from merinos and use chiefly medium-wooled types of ewes It is for this reason that three-eighths blood and quarter-blood wools predominate in the farming region In the range region comparatively few areas have sufficiently good grazing during about half of the year to support medium-wooled crossbred ewes without too costly use of concentrates Partly for this reason, three-eighths blood and quarter-blood wools form only 12 and 4 per cent, respectively, of the range-shorn wools The percentage of quarter-blood wools is small chiefly because the crossbred ewes that grow it have been bred too far away from the merino to be well adapted to the western range country Low quarter-blood and coarser wools constitute only about 1 per cent of the range production, the type of sheep that produces them not being adapted to range conditions The few such sheep in the range region are kept chiefly for the production of crossbred range breeding stock

Comparative clean scoured yields of farm and range wools Fine wools in the farming region have an average clean scoured yield of 38 per cent, as compared with 34 per cent in the range region, where the clip is much heavier with earthy matter About fifteen years ago the difference was somewhat larger, but a rapid increase in the number of sheep (almost entirely fine wools) in Texas and a rapid growth in the use of fenced ranges (which result in cleaner fleeces) has raised the average scoured yield in Texas by several points and has raised the average for range-grown fine wools by about 1 per cent (See Table 18) There is also a 4 per cent difference (44 compared with 40) in the yields of farm- and range-grown half-bloods In three-eighths bloods, however, there is a greater difference, the yield being 53 per cent for the farming and 43 for the range region The respective yields of quarter-bloods in the two regions are 57 and 48 per cent The wide differences shown by these two grades result largely from the fact that most of the crossbred range sheep spend about 8 months of the year on dusty, sparsely vegetated desert and semidesert grazing land, where their

relatively loose fleeces become so burdened with silt and sand as to partly offset their natural tendency toward a high clean yield In the farming regions, most of the sheep graze on well-grassed pastures.

The difference between scoured yields of low quarter-blood and coarser wools is much less, these yields are 58 per cent for the farm and 54 per cent for the range wools Coarse-wooled sheep in the range region usually are not grazed on dusty range lands for long periods, therefore their fleeces carry much less foreign matter than those of finer-wooled range stock.

TABLE 18

PERCENTAGE DISTRIBUTION OF RAW AND CLEAN SCOURED WOOLS, 1936–1940

Item	*Fine*	*Half-Blood*	*Three-Eighths Blood*	*Quarter-Blood*	*Low*	*All Grades*
	Production					
Production, by grades:						
Shorn * Farming region	13	9	38	35	5	100
Range region	65	18	12	4	1	100
Average, shorn wools	52	16	18	12	2	100
Pulled	26	11	37	21	5	100
Average: Shorn and pulled grease	49	15	21	13	2	100
Shorn and pulled scoured	39	14	26	18	3	100
	Clean Scoured Yields					
Average clean scoured yields						
Shorn. * Farming region	38	44	53	57	58	51
Range region	34	40	43	48	54	37
Average, all shorn †	34	40	48	55	56	40 to 41
Pulled	60	70	77	82	84	73
Average, shorn and pulled	36	44	56	61	64	45 to 46

* As shorn, i e., grease basis.
† To the nearest unit percentage.
Source. U. S Tariff Commission, compiled from trade data.

Yield of pulled wools Before sheep pelts are treated to loosen the fibers, they are washed and usually well brushed A large part of the foreign matter present in the wool is thus removed before pulling takes place. As a result, the estimated clean scoured yield ranges from an average of 60 per cent for fine to 84 per cent for low quarter-blood and coarser

The clean scoured production of each grade is also shown as a percentage of the total Because of differences in yields of the various grades, there is a striking difference between the relationship of the grades in the grease and of the grades on the scoured basis Fine wools amount to 49 per cent of the total production in the grease, but to only about 39 per cent on the scoured basis There is little change for half-bloods, but three-eighths bloods amount to 21 per cent of the total in the grease and to 26 per cent on the scoured basis. Quarter-bloods amount to 13 and 17 6 per cent and low wools to 2 and 3 2 per cent, respectively, on the two bases

Chapter 8

THE MARKETING OF WOOL

WOOL is one of the major, important commodities of world commerce In the early days virtually every family produced sufficient wool to meet its own needs There was, therefore, little or no marketing of wool. With the division of labor, however, and the concentration of population in the cities there came the demand for specialization in wool production.

Separating the center of production from that of consumption gives rise to marketing Generally speaking, the farther apart these two points are from each other the more complicated marketing becomes Wool generally can be produced more cheaply in regions that are undeveloped agriculturally Because of its relatively high value per pound wool can be transported long distances and still yield a profit to the producer Because of these facts wool production has been mostly a frontier enterprise Wool consumption, on the other hand, is greater the more densely populated the region For these reasons it is probable that wool is transported over longer distances than any other important commodity

INTERNATIONAL TRADE IN WOOL

Nearly two-thirds of the world's present supply of wool is produced in the Southern Hemisphere On the other hand, the greater part of the wool produced is consumed in the more densely populated Northern Hemisphere The five leading countries in the exportation of wool are Australia, Argentina, New Zealand, British South Africa, and Uruguay, in the order named

The leading wool-importing countries are the United Kingdom, France, Germany, United States, Belgium, and Japan The United Kingdom and the United States are both heavy producers and large importers of wool British India exports considerable quantities of wool, mainly carpet wools It imports, however, nearly as much as it exports, most of the imported wool being used for clothing purposes

Prewar Distribution of Wool Exports

Studies of the prewar distribution of wool exports made by Gerda Blau[1] reveal the following data·

The pattern of the distribution of shipments from the five chief exporting countries during the interwar period is shown in Table 1 The figures reveal the predominant share of exports sent to the United Kingdom and to the European Continent, which together amounted to 80 per cent in 1934-38, and more than 80 per cent in the preceding periods The category "Rest of Europe" includes a large number of different countries of destination, the most important being Italy, Czechoslovakia, Poland, Switzerland, and some of the Scandinavian countries

The differences between the percentage figures shown for the United Kingdom in Table 1 indicate the importance of the United Kingdom entrepôt (bonded warehouse) trade in wool. Even on the "retained" basis, however, the United Kingdom remained the largest individual

TABLE 1

DISTRIBUTION OF WOOL SHIPMENTS (GREASE BASIS) FROM THE FIVE CHIEF EXPORTING COUNTRIES, 1909-13 to 1934-38

From Five Chief Exporting Countries to	1909–13 Millions Lb Greasy	1909–13 Per Cent of Total Exports	1924–28 Millions Lb Greasy	1924–28 Per Cent of Total Exports	1929–33 Millions Lb Greasy	1929–33 Per Cent of Total Exports	1934–38 Millions Lb Greasy	1934–38 Per Cent of Total Exports
United Kingdom (retained)	385	26 6	398	24 5	435	23 2	488	26 6
France	329	22 8	376	23 1	397	21 1	325	17 8
Belgium	176	12 1	167	10 3	225	11 9	225	12 3
Germany	345	23 9	303	18 6	365	19 4	206	11 3
Rest of Europe	46	3 2	118	7 3	184	9 8	219	12 0
Total of Europe (excl U S S R)	1,281	88 6	1,362	83 8	1,606	85 4	1,463	80 0
United States	128	8 9	152	9 3	77	4 1	115	6 3
Japan	11	0 8	79	4 9	174	9 2	187	10 2
Others	24	1 7	32	2 0	25	1 3	64	3 5
Total	1,444	100 0	1,625	100 0	1,882	100 0	1,829	100 0
United Kingdom (gross import)	593	41 1	613	37 7	694	36 9	690	37 7

[1]Source G Blau, *Wool in World Economy, Part III*, Royal Statistical Soc, 1946

importer At the same time, the respective percentage shares of the three chief Continental consumers—France, Belgium, and Germany—showed a declining tendency, which was especially marked in Germany during the period of economic totalitarianism from the early thirties onward. This decline was only partly balanced by an increase in the share taken up by "Rest of Europe"

The emergence of Japan as an important wool consumer after the end of World War I is very marked This was most felt in the Australian market, where Japan's share of Australian exports rose from 2 per cent in 1909-13 to 18 per cent in 1929-33 and maintained an average of 15 per cent during the 1934-38 period

United States imports of wool were characterized by very sharp fluctuations, both in total amount and by individual countries. For instance, American imports of Australian wool rose from 9 5 million pounds actual weight in 1935, to 32 million in 1936, to 69 million in 1937, and then fell again to 6 5 million in 1938

The erratic changes in United States consumption of foreign wools during the interwar period were due partly to the effects of the American wool tariff, which restricted imports to the varying margins between total demand and domestic supply The pre-

TABLE 2

WOOL EXPORTS FROM FIVE SOUTHERN HEMISPHERE COUNTRIES, ACTUAL WEIGHT, AVERAGE 1934–38, ANNUAL 1939–45

(In millions of pounds)

Year *	*Australia*		*New Zealand*		*Union of South Africa*		*Argentina*		*Uruguay*		*Total*	
	To U.S	*Total*	*To U S*	*Total*	*To U S*	*Total*	*To U S*	*Total*	*To U S*	*Total*	*To U.S*	*To all Countries*
Average 1934–38	26	827	15	263	2	231	53	305	15	115	111	1,741
1939	17	862	14	277	37	181	137	282	37	106	242	1,708
1940	278	537	3	199	29	60	349	418	120	145	779	1,359
1941	558	816	14	205	199	288	220	243	43	58	1,034	1,610
1942	348	557	15	209	38	100	153	178	98	105	652	1,149
1943	262	509	27	244	20	52	199	225	100	110	608	1,140
1944	260	562	33	123†	21	88	199	266	174	204	687	1,243
1945‡	340	775	116	349	129†	390	360	520	100	160	1,045	2,194

* Year beginning July 1 in Australia, New Zealand, and South Africa, October 1 in Argentina and Uruguay

† Declared exports to the United States

‡ Preliminary estimates based on incomplete statistics Compiled from official sources by Office of Foreign Agricultural Relations

Source U S Dept of Agriculture, *Livestock and Wool Situation*, Oct. 1946, p 16

war domestic wool clip showed a fairly steady average of about 430 million pounds per annum, and was generally absorbed in the internal market year by year Hence, a moderate increase or decrease in American consumption caused a relatively heavy rise or fall in the size of imports

During the World War II period, the United States became the most important buyer of Southern Hemisphere wools, a position which it has held continuously since 1940 Wool exports from the five Southern Hemisphere countries to the United States and the rest of the world are shown in Table 2 In the 1945-46 season, shipments to the United States, including both apparel and carpet wools consisted of about 1045 million pounds, amounting to almost half the total shipments from the five countries Compared with the 1934-38 average, these shipments are almost ten times as large

Marketing Wool in the United States

The leading wool market of this country and the second largest wool market of the world is Boston Receipts of foreign and domestic wool at Boston amount to 300 million to 400 million pounds

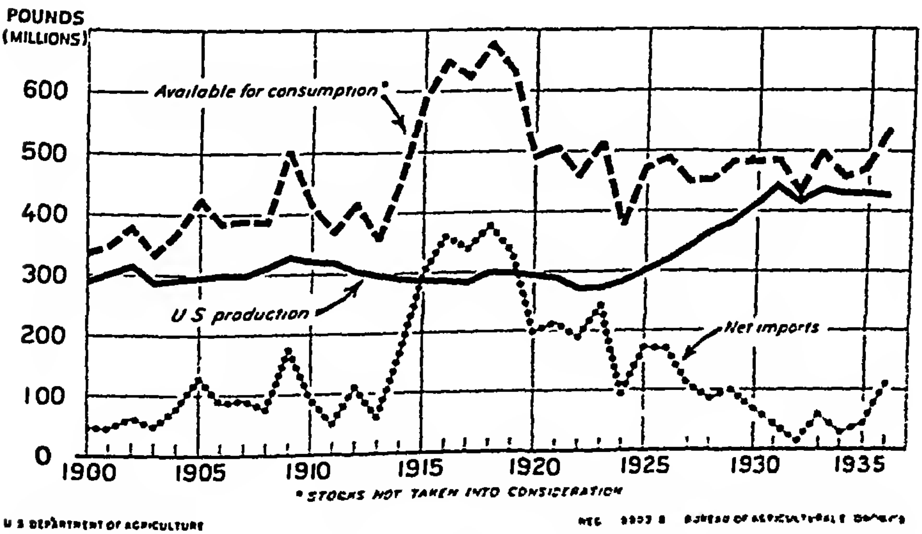


Fig 1 Wool, combing and clothing Production, net imports and consumption, U S, 1900-1936

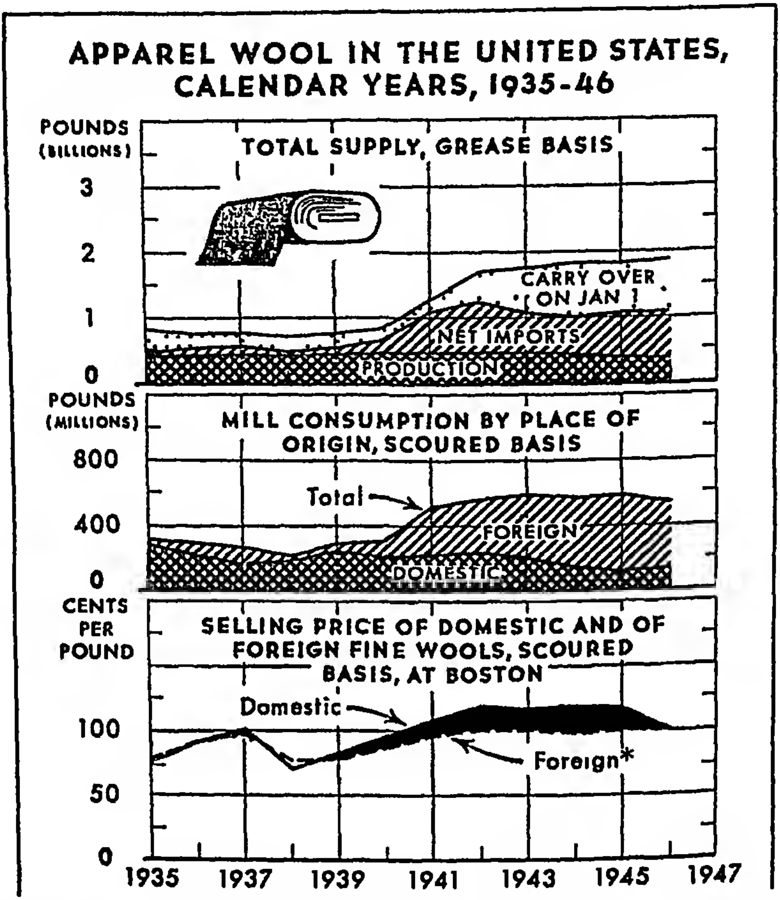


Fig 2 Source Bur of Agricultural Econ, U S Dept of Agriculture

per year. Boston handles approximately 75 per cent of the domestic wool and occasionally as high as 75 per cent of the imported wool Other cities important as wool markets are Philadelphia, which handles considerable quantities of domestic and foreign wools, and New York, which receives large amounts of imported wools The estimated domestic production, net imports, and estimate consumption of combing and clothing wools for 1900 to 1936 are illustrated in Fig. 1. The total supply, mill consumption, and selling prices of domestic and foreign apparel wools for 1935 to 1946 are shown in Fig 2

There are, according to J F Walker,[1] three main methods by which the wool clip of the world is marketed today.

[1]In the "Golden Hoof," Sheep Breeder, 1936

1. Direct buying or speculative buying
2. Co-operative marketing through private sales
3. Auction selling by open competitive bidding

In the United States practically the entire clip is marketed by the first two methods Approximately 70 per cent of wool is sold through direct buying The methods of marketing have changed somewhat from time to time and there are also some variations in different parts of the country However, the general plan of marketing does not differ materially from that in use in the early days The more important agencies involved in getting the wool from the producer to the consumer are. the country buyer, the country assembler, the central-market dealer, the commission merchant, the broker and the manufacturer.

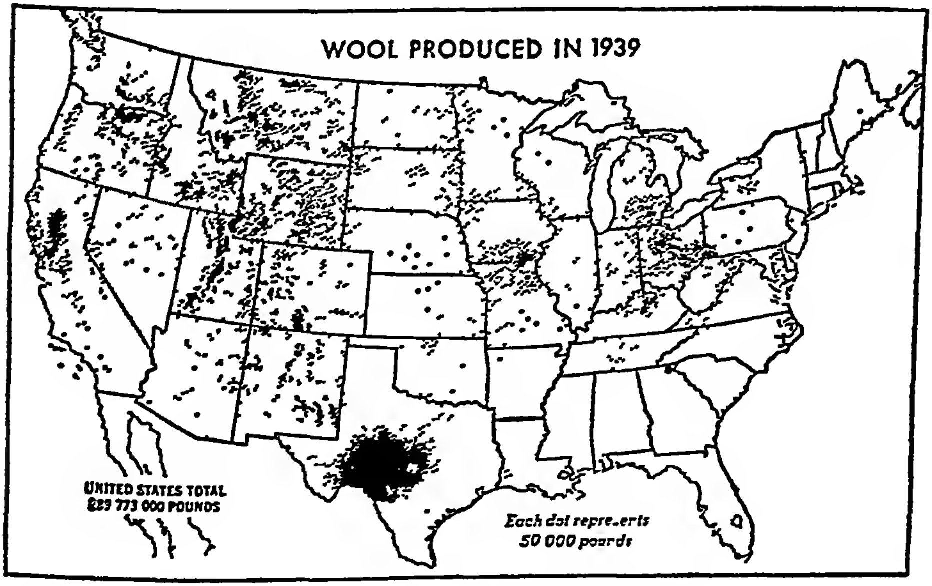


Fig 3 Intensity of wool production in the United States *Courtesy USDA*

In the farm states, which include the central and eastern states, the country buyer gathers up lots of wool and either sells them to some merchant in town or stores the wool in his own warehouse The farms have, on the average, approximately fifty head of sheep, but the number may vary from three up to 2500 head, which is considered quite large. The central-market dealer sends his agents

through these small towns or farmer-owned warehouses to buy the wool as it is suited to his needs The wool is then shipped to some large center where it is graded on the basis of mill requirements and finally sold to the manufacturers

In dealing with the farmer, the country merchant will, at times, secure the wool in exchange for necessities The local purchaser may be a junk dealer or peddler, who goes around the country, buying up the wool or exchanging it for his own merchandise Numerous merchants in the larger cities specialize not only in wool, but also in other products grown in that particular state such as furs, cattle, or swine They buy the wool from the country buyer and may have at times secured such large amounts of wool that they resell to the wool merchants in Boston, Philadelphia, St Louis, and Chicago as well as directly to the mill Many times these wools are ungraded and the price is set for the wool "as is" In other instances they may be roughly graded in three classes fine, taking in the fine and the half-blood, medium, containing the three-eighths and coarser wools, and rejects, consisting of faulty fleeces, or those which have a very limited market because of their color. "Burry," "seedy," "cotted," or closely matted fleeces and those that are "black," "brown" or "gray" in color are all classed as "rejections"

Another form of marketing is that in which the growers consign their wool to wool-warehouse companies They usually obtain advances amounting to a certain percentage of the market price of their wool The warehouse company grades the wool and holds it for inspection and purchase by the broker or mill agent At times, the warehouse company may remit to the grower the price obtained less any advances that may have been made, interest on money already advanced, and a certain charge per pound for grading and carrying

Selling of the western wool grown in the range states is quite different from selling that grown in the farm-flock states The wool merchant sends his own agents directly to the shearing shed or warehouse of the wool grower during the shearing season This buyer may be a local man living in the range state all year around, or he may be a man sent directly from Boston In the first instance, the local buyer works on commission, which runs usually ½ to 2 cents a pound on wools purchased, whereas the Boston man is normally paid a salary and his traveling expenses Some eastern wool brokers go west with purchasing orders from different merchants or mills to purchase specified quantities of various types of wool

This is done especially by larger mills, which desire to purchase in advance wool suitable for sale requirements, and in such cases the buying broker charges ½ cent per pound for purchasing He pays the grower by drafts and attends also to the shipping In some years, especially when higher prices are anticipated, the sale of the clip is contracted weeks or months before shearing The contract normally provides an advance payment to the grower.

This system of buying the wool off-the-sheep's-back is now generally considered unbusiness-like, because it is too much of a gamble If the wool declines in price, the wool grower makes a good profit On the other hand, if the price has advanced before or after shearing, he may lose large sums of money The wool grower gambles that prices will be lower, whereas the purchaser gambles that prices will be higher

In dealing directly with the wool grower, the wool buyers sometimes offer the grower their bids under seal and each ranchman or group of ranchmen reserves the right to accept or reject any or all bids Much wool from the ranches is also consigned to commission houses in large wool centers, most of it going to Boston, Philadelphia, Chicago, and St Louis and other Missouri river points. From the Washington-Oregon-Idaho district, consigned wool goes to Portland, Oregon.

The idea of co-operative marketing has taken hold in wool marketing In 1918 the wool clip of the United States was commandeered as a war measure In this act provisions were made for fixed wool prices as well as fixed commissions for the wool dealers In order to secure the price for their wool that the government had fixed, a group of Ohio men organized the Ohio Wool Growers Co-

systems have been tried, ranging from very simple and temporary organizations handling sealed bids that are accepted or rejected by the sales committee, to permanent, incorporated organizations serving in the capacity of commission houses and dealing on the basis of binding, legal contracts with the growers The largest co-operative enterprise is the National Wool Marketing Corporation, founded in 1929 at Boston, Mass The total volume of wool handled by its members varied from 116 million pounds in 1930 to 31 million pounds in 1935, according to Bulletin 3 of the Farm Credit Administration The results of some of the co-operative selling indicate that it helps to make competition among buyers even more keen and that it facilitates business-like transactions The main principle is to sell wool of such qualities as the market will absorb, this principle alleviates to a certain degree heavy overloading and serious depressing of the market Up to World War II this co-operative wool organization handled annually from 15 to 30 per cent of the domestic clip

A striking peculiarity of the wool market of United States is

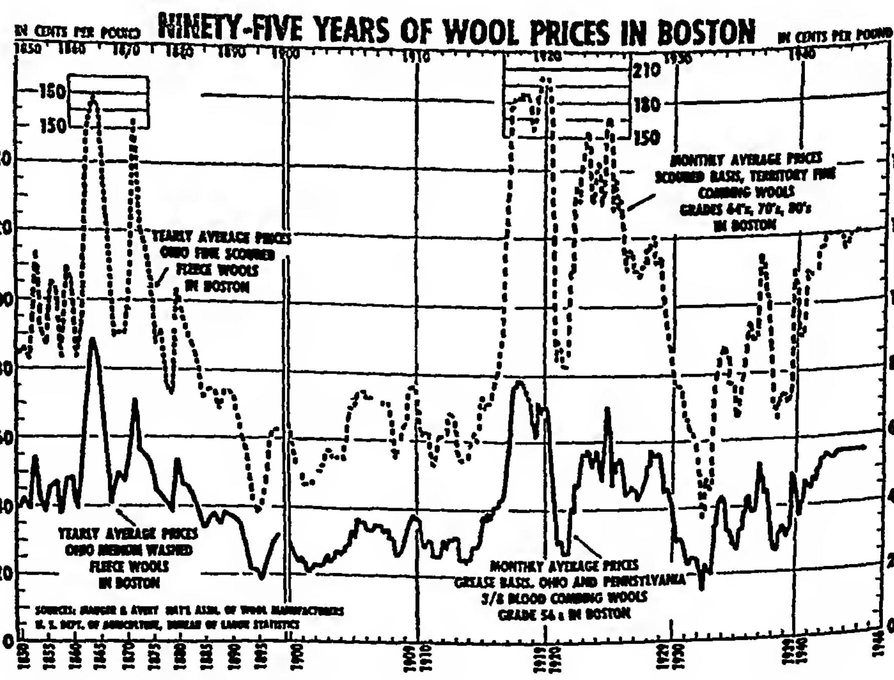


Fig 4

the fact that, although from 550 million pounds to 750 million pounds of wool with a total valuation ranging from $112,000,000 to $350,000,000 are handled annually, there is no established public market for this important commodity Practically all of this vast quantity of wool is bought and sold by private agreement Another peculiarity is that while there is no open public or auction market a very large proportion of the wool passes through two or three leading centers. In other words, the marketing of wool is probably more concentrated than that of any other important commodity

Recently efforts have been made to establish auction marketing for wool in the United States Some marketing efforts in the last forty years have been advertised as auctions, but, in reality, they were merely sealed-bid sales In 1900 a first attempt was made in New York City In 1916 the Philadelphia Wool Auction was organized but was unable to have a single sale because of the war At the close of World War I, the United States government, which had found it necessary during the war to take over the entire wool clip, and also importations and options on importations, had in its possession 460 million pounds of wool It was decided that the fairest method of disposal would be by auction The first sale, which was held December 18, 1918, was followed by others at intervals during the next three years, so as to interfere as little as possible with the marketing of the domestic clips The final sale was held March 2, 1922

Many times since these government wool auctions, the advisability of selling their wool by auction has been discussed by various groups of growers In order to get information about auction procedures in other wool-growing countries, J F Walker was sent to Australia, New Zealand, and South Africa in 1927-28 by the United States Department of Agriculture A bulletin on this study was published in June 1929

In 1934, at Ogden, Utah, a private concern held the first of the present day auctions This same concern, in 1936, opened auctions at Denver and, in 1940, at Billings and Miles City, Montana, and at Boston Auctions were held by a private individual in 1939-40 at San Angelo, Texas, and a co-operative opened auctions at Portland, Oregon, and at Stockton, California, in 1940 In 1940, ten auctions were held in seven states

Wool auctions have made a slow but steady growth In 1935, the auctions handled 2 7 per cent of the total production of their areas and in 1940, this percentage increased to 7 7 Earlier figures are not available

The wool offerings at all series of sales at any one point from 1934 through 1940 varied from a low of 428,000 pounds to a high of 6,500,000 pounds with a total of 54,341,000 pounds offered. Of this, 51 per cent or 27,453,000 pounds were sold The percentage of the amount offered which was sold at the various sales ranged from 9 4 per cent to 94 per cent.

Marketing Wool in Other Countries

The marketing method prevailing in other countries is by auction in open competitive bidding England first introduced this method and it was natural that her colonies followed her example At first, the wools were all moved to the consumption centers, but as the production grew larger, selling of wools at their point of origin was begun London has been displaced as the greatest wool marketing center of the world by Sydney, Australia, with Boston and Buenos Aires following in that order All wool sold by this method is normally carefully classed and baled at the farm Each bale is marked according to the quality of wool it contains. The wool is then consigned to brokerage houses which will take care of the selling at the auction places These houses do not buy or sell wool on their own account but do business on a strictly commission basis

London Wool Auctions

The London auction sales were for many years the price barometer of wools used in the manufacture of clothing They are held six times a year, that is, every two months During the progress of each day's auction sale a limited number of bales (from 10,000 to 12,000) is offered in large well-lighted warehouses In London, each bale of every lot, which may run from 2 or 3 bales up to 20 bales, is opened at the top for inspection and drawing of samples Printed catalogues are provided previous to the day of sale which give for every lot the clip marks, the classification and the grade, the number of bales, and other descriptions marked on the bale

Through long experience the buyer is able from the details given in the catalogue to select the lots in which he is most interested. The next morning as soon as the warehouse opens he examines the lots that he has marked in his catalogue Based on his visual examination he will make notations in his catalogue as to the value of the lots and his desire to bid on this wool He is guided in his judgment by type samples which have been furnished him by the

Wool Marketing in Australia and New Zealand

The Australian market is operated on the same lines as the London market The farmer usually consigns the clip to wool brokers in Sydney, Melbourne, Brisbane, Adelaide, or Geelong The broker holds no contract with the grower for the delivery of his wool except as he may have a claim to it on money advanced This holds true for the co-operatives as well Under these conditions the grower is at liberty to consign his wool to the concern which he thinks is able to give him the best service or net him the greatest return for his wool

The wool house does a strict brokerage business and buys no wool for its own account Wool is sold or catalogued for sale in the order in which it arrives at the broker's warehouse, and at least 20 per cent of the total clip must be in store to constitute an entry Advances on wool may be made upon such terms as the grower and the broker may agree upon There is no specific rule covering the amount or rate of advance, except as may be agreed upon in conjunction with the Australian Wool Growers Council

The broker furnishes storage space for holding the wool and show floors for displaying auction lots, and covers it with insurance

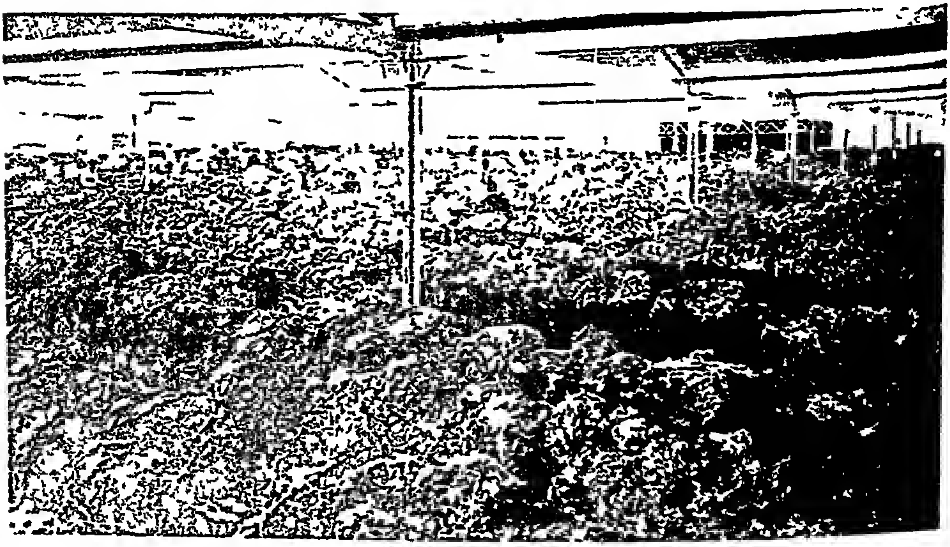


Fig 5 Dalgety's show sales room, Melbourne, Australia

In contrast to the London practice, only a certain percentage of each lot offered for sale is opened and displayed on the show floor in the warehouses In 5 to 10 bale lots, 3 bales are shown; 20 per cent of lots of 10 or under 20 bales, 15 per cent of lots of 20 bales or over and under 100 bales; and 10 per cent of lots of 100 or over These bales are drawn at random to represent as fairly as possible the entire lot (Fig. 5)

These stores are normally open from 6 o'clock in the morning Two brokers' catalogues are offered daily, containing a combined offering of not more than 12,000 bales, the limit per day Buyers must begin very early if they wish to view all the wool offered, as the auction starts punctually at 3 o'clock in the wool exchange

To place an order to purchase a certain amount of a known grade of wool in Australia, a concern or mill in the United States would first go to the various Boston representatives of the Australian wool buyers After selecting the grade desired they send a cable giving the number of bales desired, and the limit they will pay on the basis of C & F Boston (which means Cost and Freight delivered in Boston) The buyer in Australia at the auctions purchases the wools at a price which includes the charges for purchasing the wool and loading it onto the boat, plus the cost of transportation The concern or mill, however, must pay the insurance unless otherwise specified. Due to the fact that the premium varies ac-

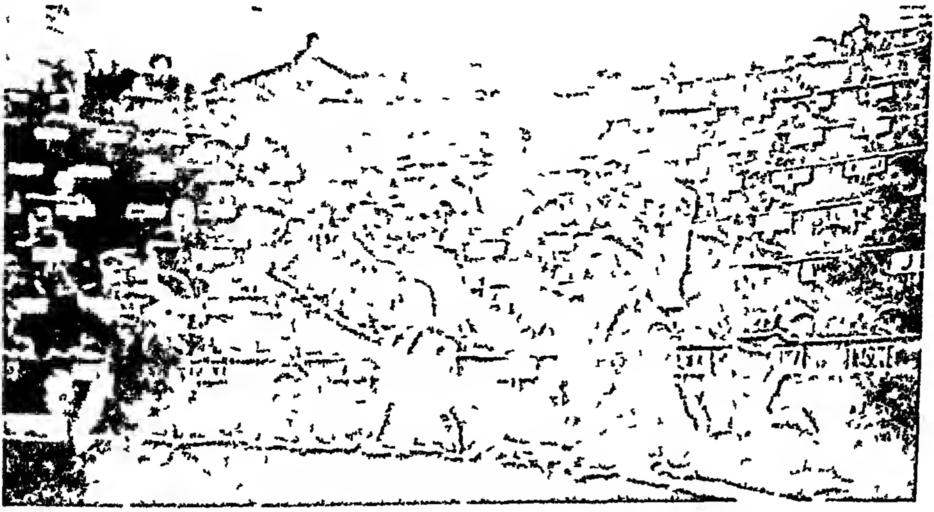


Fig 6 Wool auction at Melbourne, Australia *Courtesy Textile Journal of Australia*

cording to the boat on which the wool is shipped, the cost cannot be estimated previous to purchasing

When an order has been executed, a letter of credit, in pounds sterling, is drawn on a London bank, because London is the bank center for all wool purchases made in Australia Original weights are always taken The only time the wool is weighed is when the Australian grower ships it to the warehouse of his selling broker or house It is not reweighed when shipped to the concern or mill The mill or the broker reweighs the bales after they have been received, and should there be a significant error in the invoice or original weights, the concern or mill will make a claim to the local representative, who will forward the claim and secure an adjustment

In *New Zealand* the wool is sold in the same manner as in Australia Six auction sales are held during November and December at Wellington, Napier, Christchurch, Nelson, Timaru, and Invercargill

Wool Marketing in South America

In the South American markets the mills or wool brokers purchase grades or classes by methods similar to those of Australia,

although no auctions are held in Argentina or Uruguay The wools are purchased by large packers or merchants who do their own grading or classing Many times the clips are consigned to brokers, who grade or classify the wool and offer it for sale direct to dealers and mills all over the world Types of various broker's wool, as they classify it, are in the hands of their representatives in the United States and in Europe Cables are sent to the various representatives giving the number of bales of certain grades they can offer, the estimated yield, and the price desired in the grease, the terms being C I.F., which means cost, insurance, and freight prepaid to Boston, London, Antwerp, or wherever the cable is sent

TABLE 3

EXPORT OF MAIN SOUTH AMERICAN WOOLS

ARGENTINE SHIPMENTS

	Average 1935–39 Bales	*1940 Bales*	*1941 Bales*	*1942 Bales*	*1943 Bales*
United States	74,264	363,916	225,556	131,000	214,218
Continent	145,940	23,649	7,239	5,500	—
United Kingdom	88,306	9,005	2,486	—	—
Various	23,426	40,954	17,956	13,500	38,100
Total exports	331,936	437,524	253,237	150,000	252,318

Average weight of bales 980 pounds

URUGUAYAN SHIPMENTS

	Average 1935–39 Bales	*1940 Bales*	*1941 Bales*	*1942 Bales*	*1943 Bales*
United States	20,760	118,038	48,967	96,300	98,955
Continent	62,487	12,008	17,026	4,500	—
United Kingdom	15,770	—	6,815	—	—
Various	12,008	13,159	6	2,800	9,466
Total exports	111,025	143,205	72,814	103,600	108,421

Average weight of bales 970 pounds

PERCENTAGE OF SHIPMENTS TO THE UNITED STATES

	1935–39	*1940–43*
Argentina	22 4	85 5
Uruguay	18 7	84 6

Source *Dalgety's Annual Wool Review for Australia and New Zealand*, 1944 45, p 75

The local representatives, as soon as they receive a cable from their principal, send out to their prospective customers a letter giving a copy of the cable, and thus circularize the particulars of their offerings A customer makes an offer on a quantity of the particular wool he desires, and if the offer is accepted the wool is shipped and a letter of credit from a local bank in dollars is secured

The most important wool-marketing centers of South America are Buenos Aires for Argentina, and Montevideo for Uruguay The wool season in South America is calculated as from the first of October to the thirtieth of September From 1928-1934, the average export from Argentina amounted to 346,958 bales, whereas for the same period of time the shipments from Uruguay were 116,640 bales, according to *Dalgety's Annual Wool Review* For the five seasons from 1935-39, the total export for Argentina was 331,936 bales and for Uruguay, 111,025 bales Table 3 shows export figures for the World War II period (1940-43). In considering these figures, it must be borne in mind that the South American bale is three times as heavy as the Australian bale The total export would be approximately equal to 1,390,794 bales of Australian proportion

Wool Marketing in South Africa

In South Africa modern methods of wool selling have developed, largely from about 1920 on, almost coincidental with the betterment of the wool production Previous to this time the South African clip was purchased the North American way through speculative buyers or local merchants, who financed the farmer through the year and took his wool in payment of his debt. For many years the wool prices were stabilized for the farmer at about 15 cents per pound Government control during World War I and the higher wool prices brought decisive changes in this old method of wool selling. In 1927 about 90 to 95 per cent of the wool of the Union of South Africa was handled on a brokerage basis for the account of the producer or through his own co-operative associations The four main wool marketing places are East London, Durban, Port Elizabeth, and Capetown The methods of marketing vary somewhat in different centers as to minor details, but in the main they are similar Each wool center maintains an organization of brokers for controlling wool movements and prices in that particular market The wool growers have no organization but their interests are represented to a certain extent by the brokers, whose local organiza-

tions enter into agreements with the buyers as to terms of sale, quantities offered and withdrawals The most rapidly growing wool center is Durban, where strict rules covering wool selling are enforced by the Durban Wool Brokers' Association Weekly sales are held there beginning in November and ending early in April In Capetown and Port Elizabeth some wool is purchased through private agreement between the buyer and the broker. At East London, the bulk of the wool is disposed of through private agreements There is no agreement to prevent buyers from obtaining wool direct from growers or store keepers, except at Durban In the field of co-operative marketing, considerable headway is being made in the Union and several co-operative wool-marketing organizations are now in operation These co-operative organizations operate on a brokerage basis.

Other European Wool Markets

Other important wool-marketing places are: Liverpool, which specializes in carpet wools, such as wool from India and alpaca from South America The Liverpool sales are auction sales conducted in the same manner as in London The most important Continental centers are Antwerp, Hamburg, Bremen, Le Havre, and Marseilles South American wools are marketed at Antwerp, whereas in the other cities wools have been purchased by dealers in the country of origin European countries are heavy buyers of scoured wool, especially from Australia Large quantities of wool known as *off-sorts,* which are obtained by skirting, are graded and scoured in the country or origin As these wools have an exceedingly heavy shrinkage, a considerable saving is made on transportation charges and they can be presented for sale in a more attractive condition than would be the case if they were offered in the original greasy condition

WOOL CONTROL DURING WORLD WAR II

United States Wool in World War II

Domestic wool growers began to campaign early in 1942 for the federal government to purchase the entire domestic wool clip at ceiling prices established by the Office of Price Administration In

February 1942 specific dollars-and-cents ceiling prices were established for domestic wools These ceiling prices were substantially higher grade for grade, than the duty-paid prices of imported wools It was apparent that if domestic wools were held for ceiling prices their use would eventually be restricted to government business

TABLE 4

COMMODITY CREDIT CORPORATION PURCHASE PRICES AND SELLING PRICES FOR SELECTED GRADES OF DOMESTIC WOOL (SCOURED BASIS), 1946

Grade	Purchase Price	Selling Price: Effective Beginning August 5	Selling Price: Effective Beginning October 14
Territory Wools			
64s and finer			
Strictly staple	$1 21	$1 02	$1 07
Average to good French combing	1 18–1 19	1 00	1 03
Half-blood			
Good French combing 60s or finer	1 17	0 97	1 03
Staple, bulk 60s	1 16	0 97	0 98
Three-eighths blood			
Strictly staple 58s–56s	1 09	0 92	0 96
Good French combing 56s	1 04	0 90	0 92
Quarter-blood			
Staple 50s	1 00	0 87	0 90
Staple 48s–50s	0 96	0 87	0 88
Low Quarter-blood 44s–48s	0 93	0 75	0 80
Bright and Semibright Fleece Wools			
64s and finer			
Staple and big French combing	1 21	1 04	1 09
Average to good French combing, bright	1 15–1 17	0 97	1 01
Average to good French combing, semibright	1 15–1 17	0 97	0 97
Half-blood			
Staple 60s–58s	1 14	0 97	0 97
Short French combing	1 10	0 92	0 90
Three-eighths blood			
Staple 56s–58s	1 04	0 90	0 93
Short French combing 56s–58s	1 00	0 82	0 86
Quarter-blood			
Staple 50s–48s	0 96	0 87	0 87
Low quarter-blood 44s–48s	0 90	0 72	0 72

Source Compiled from Production and Marketing Administration, price schedules

Confronted by these prospects, and fearful of a repetition of the sharp drop in wool prices which occurred after the close of World War I, wool growers appealed to the government to purchase the entire domestic clip at ceiling prices for the duration of the war and for two years thereafter. As a result the Department of Agriculture took over the 1943 domestic clip together with such part of the 1942 clip as remained in the hands of the growers

The War Food Administration issued Food Distribution Order 50, which provided that with certain exceptions all domestic wool not sold before April 25, 1943, must be sold to or for the account of the Commodity Credit Corporation. The C.C.C. purchased 223,000,000 pounds of domestic wool in 1943. Resales during the year amounted to 52,000,000 pounds, leaving unsold stocks of 171,000,000 pounds at the end of 1943. Since only the government was willing to pay the premiums necessary to obtain fabrics made from domestic wool the government was substantially the only customer.

From the beginning of the program until August 1945, sale of domestic wool to the Corporation was mandatory, with minor exceptions After restrictions were lifted, wool continued to move largely to C.C.C because its purchase prices were higher.

Sales of domestic wool were largely for military orders during the first two and a half years of the program. Little domestic wool was purchased for civilian use because imported wool was available at much lower prices Sales in each season were much smaller than purchases and consequently large stocks accumulated, although sales for civilian use increased after selling prices were reduced in November 1945 After the end of the war, much pressure was brought on the government agencies to turn the wool marketing over to private enterprise. The government yielded to this demand by setting a final deadline for April 15, 1947. On August 15, 1947, the wool price support bill (S. 1498) went into effect authorizing the C.C.C to purchase the domestic wool clip until December 31, 1948.

British Empire Wool in World War II[2]

Control of the British Empire supplies of apparel wools during World War II was organized much more quickly and, on more stringent lines than during World War I. Two weeks after the outbreak of war, the British government announced the conclusion of agreements to purchase the entire Australian and New Zealand

[2] G Blau, *Wool Digest of the Int Wool Secretariat*, June 17, 1946, pp. 10-12.

wool clips for the duration of the war and one wool year thereafter Six weeks later, an agreement with the South African government was concluded

With the purchase of the Dominions' clips, the British government had become the sole importer of these wools, and United Kingdom imports from South America were also brought under government control The London wool auctions were discontinued immediately after the outbreak of war and the normal functions of private importers and brokers ceased Practically all processing up to and including combing was done for the Wool Control on a commission basis In the case of all government contracts, qualities were specified by the Control In regard to other requirements, manufacturers were given a limited right of selection but the range of available raw materials for civilian uses was largely determined by military priorities and by the shipping situation, which made it essential to give preference to shipments of wools with high clean yields

South American wools continued to be sold in a free market with the United States being by far the largest buyer throughout the war period

World Consumption during World War II

The wartime rate of American wool consumption rose to the all-time record of around 1000 million pounds grease basis per annum Consumption in Australia, Argentina, and India also increased considerably The higher rate of consumption of these countries was, however, far from sufficient to make up for the loss of markets on the European Continent and, from the end of 1941 onward, in Japan Wartime civilian supplies in the United Kingdom were reduced to about 35 per cent of the prewar level and the over-all rate of United Kingdom wartime consumption was about one-quarter below prewar

On balance, world consumption during the war could only absorb about two-thirds of current supplies from the five main exporting countries, which meant that by the summer of 1945, i e, after nearly six years of war, the accumulation of stocks in the Dominions and the South American countries had reached a total equal to about two years' supply.

In view of this vast accumulation of stocks, the governments of the United Kingdom and of the dominions of Australia, New Zea-

land, and South Africa decided that the time had come for co-ordinated plans for postwar disposals At an intergovernmental conference held in London in April and May 1945, agreement was reached on a new Empire marketing scheme

The stock of all Dominion-grown wool owned by the United Kingdom government on July 31, 1945, was transferred to the joint ownership of the United Kingdom government and the three Dominion governments concerned, and a Joint Disposals Organization was set up for the purpose of buying, holding and selling wool on behalf of the four governments

World stocks of apparel wool at the beginning of the 1946-47 export season, estimated at about 5 billion pounds grease basis, were about three times the normal prewar stocks Stocks of Australian, New Zealand, and South African wool held by the British Joint Organization on June 30, 1946, totaled about 2,150 million pounds grease basis—many times larger than prewar average carry-over of the British Dominions and larger than the current annual production of those countries Large privately-owned stocks were held in Argentina.

In the United States, mill and dealer stocks of domestic and imported apparel wool and stock held by the Commodity Credit Corporation on September 28, 1946, were estimated at 1000 million pounds grease basis against a prewar average stock (1935-39) of 287 million pounds

In interwar years, world production and consumption of wool were about in balance Changes in demand were largely reflected in sharp fluctuations in price World consumption of apparel wool in the year ended June 30, 1946, probably was about up to the 1934-38 average consumption and was about equal to world production As no reduction in world production is anticipated, liquidation of the wool surplus must be achieved by expanding world consumption Any prospective increase in wool consumption in the postwar years will most likely occur in Europe as rehabilitation progresses In prewar years Europe was the world's largest wool consuming area Continental Europe took one-half of world imports of apparel wool in 1934-38 and an additional one-third went to the United Kingdom A sustained increase in consumption will depend upon (1) improvement of purchasing power, particularly in low income countries, (2) expansion of prewar outlets, and (3) reasonable prices for wool in relation to other textile fibers Wool will face increasing competition from synthetic fibers, which have been much improved and have been reduced in price compared with prewar prices This

competition will be more severe should consumer purchasing power decline

AMERICAN DUTY ON FOREIGN WOOLS

In buying foreign wools the American wool merchant or mill has to take into consideration the duty on foreign wools as levied by the United States Customs The Hawley-Smoot Tariff Act, Wool Schedule 11, has been enforced since 1930 Paragraph 1102 states that the duty on wools not especially provided for, and hair of the Angora goat, cashmere goat, alpaca, and other like animals in the grease or wash, will be 34 cents per pound of clean content, scoured, 37 cents per pound of clean content, on the skin, 32 cents per pound of clean content, and sorted, or matchings, if not scoured, 35 cents per pound of clean content Therefore, wools which are used in the manufacturing of wool goods must pay a duty of 34 cents, based on the yield of scoured and carbonized content In other words, if imported wools are estimated to shrink 40 per cent, only 60 pounds of each 100 pounds must pay a duty of 34 cents a pound For example, when 100,000 pounds of foreign wool, with a shrinkage of 40 per cent, is imported, the importer has to pay the government 60,000 times 34 cents, which is $20,400

In this country hardly any wool suitable for carpet purposes is grown Therefore, wool for the manufacture of carpets and floor coverings are admitted duty free

In case the wool is not desired for immediate sale by a wool dealer, who plans to hold it for resale or for a mill, the wool is taken from the pier and stored in a bonded warehouse This bonded warehouse may be at the point of import or it may be connected with the mill At either place it will be in charge of a custom official The withdrawal of bales from the bonded warehouse can be done only after the duty is paid and a permit obtained from the custom house This permit is in turn presented to the customs official, who is stationed at the bonded warehouse where the wool is in store, and who releases the number of bales paid for

The owner may keep his wool in bond without paying the necessary duty for three years After the three years lapse he must withdraw it, and pay the duty or else re-export the wool into another country, thus avoiding the payment of the duty In many instances local dealers have purchased foreign wools, storing them in bond in this country and have sold them abroad In the event the owner

is not able to dispose of the wool after three years he may apply to the custom house officials for an extension, which will be granted if the officials believe the reason warrants it

In purchasing foreign wool, the wool dealer or the mill agent will always consider the duty, which sum has to be added to the actual purchasing price He has to see that the out-of-bond price does not exceed the price at which similar domestic wools can be bought As a rule foreign wools sell in our markets at prices higher than those paid for domestic wool of comparable grades Many wool growers have been inclined to question this apparent disparity, which attracts foreign wool to this country in spite of the tariff In an effort to analyze this apparently contradictory situation, the Bureau of Agricultural Economics made a study of the factors that affect relative value of domestic and foreign wools In Table 5, which was compiled by Buck,[3] a comparison is made between domestic and foreign wools in which the principal factors tending to influence wool values are shown

TABLE 5

COMPARISONS BETWEEN DOMESTIC AND FOREIGN MARKET WOOLS

Factors Influencing Values	*Domestic Wools*	*Foreign Wools*
Preparation of fleece	Entire fleece bundled, including inferior and heavy parts grown on belly, legs, and neck	Bundles are composed of only good body wool, inferior parts removed in skirting
Tags	Amount varies	None
Britch	Bundled in fleeces	Removed at time of skirting
Heavy dung locks	Often bundled in fleeces	Removed prior to shearing or when fleeces are prepared for market
Stained	Skirts, bellies, dirty locks, etc , are rolled in fleeces	Removed in skirting
Paint	Fleeces from some sections very heavily painted; average considered high	Relatively small amount
Burrs, seeds, straws, etc.	Even though necks, skirts, or other parts of fleece are burry or chaffy, they are bundled in fleece	Burry and seedy fleeces are kept separate Parts of fleeces containing vegetable matter are removed in skirting

[3] W A Buck, U S Dept of Agric. pamphlet, 1933.

TABLE 5—*Continued*

Factors Influencing Values	*Domestic Wools*	*Foreign Wools*
Stuffed fleeces	Occasional fleeces from some sections contain heavy foreign material for weight Found to a greater degree in wool from farming sections	Rarely found
Strings	Mostly paper, an occasional fleece carries harmful tying material.	Seldom tied
Gray, brown, and black	Often shows lack of care in keeping colored wool separate from white Much wool carries occasional colored fiber Care in separating colored from white fleeces would tend to broaden use in instances where whiteness is required	Care is exercised to keep colored fleeces separate from white Comparative freedom from black fibers in wool from Australasia and South Africa stimulates a demand for their use in white yarns and fabrics and in dyed pastel shades
Staple lengths	Somewhat irregular	Comparative regularity due to special effort to supply product as desired Classed for staple length at time of preparation Usually only superior type of wools are imported
Shrinkage	Comparatively heavy.	Much lighter Australia 50 per cent New Zealand 40 per cent South Africa 55 per cent South America 50 per cent
Dead (murraine)	Fleeces found at times intermixed with good wool Pieces stuffed or bundled in good wool	None
Packing	Occasionally extraneous heavy articles packed in bags with fleeces	False packing is rare.
Sorting cost	Comparatively high, caused by necessity of eliminating greater quantity of extraneous matter	Lower because of minimum amount of extraneous matter
Preference of manufacturers	Types of fabric or yarn desired and relative cheapness of the wool exert considerable influence on kind selected. Manufacturers make allowance in price to take care of heavier shrinkage and greater manufacturing costs	Wool from Australasia and South Africa often preferred for pure white fabrics and for use with lightest shades of dye

Apparently little can be done at present by the American wool growers to overcome the advantages possessed by foreign wools through their lighter shrinkage. But it is apparent that the domestic wool can be improved through greater care in the preparation of the fleeces for the market. Improvement in the preparation of the individual fleeces would eventually provide a basis for beneficial changes in methods of marketing.

PULLED WOOL

Pulled wool is the term applied to wool that has been removed from the pelts of animals slaughtered largely in the packing houses In fact, pulled wool is a by-product of the slaughtering and meat-packing industry The importance of this type of wool for the American wool trade is best illustrated by the fact that the amount of pulled wool produced in the United States for the ten years 1931-1940 amounted to 65,000,000 pounds annually. Compared with 364,000,000 pounds of sheared wool, this figure amounts to 15 per cent of the total annual domestic wool production During World War II (1941-45), the ratio of pulled wool to shorn wool was 67,-000,000 to 367,000,000 pounds An all-time high of 71,000,000 pounds of pulled wool was reached in 1944.

The pulling is conducted in the pulleries which, in the United States, in most instances, are connected with the large slaughter-houses The most important wool-pulling establishments are located in Chicago, St Louis, New York, and St Joseph and Kansas City, Missouri, and are in the hands of such well-known meat packers as Swift & Co, Armour & Co, Morris & Co, Wilson & Co, and a few others There are about forty pulleries in the United States A quarter of the total pulled wool is produced in the eastern part of the United States Numerous other names are used in the trade for pulled wool, such as skin wool, slipe wool, tanners' wool, and glovers' wool

Methods of Pulling Wool

The removal of the wool is done by three principal methods, namely, the sweating, the lime, and the depilatory processes After the sheep have been slaughtered, the skins are stripped from the bodies and the pelts are transported to the wool-pulling establish-

ments The most valuable part is the skin, but before the skin can be tanned and converted to leather it is necessary to remove the wool.

1 *Sweating process* In this process the wool skins are hung on racks in large, heated rooms in which the atmosphere is artificially moistened The skins are hung very closely together Through the action of the heat and the moisture on the skin, the roots of the wool fibers are loosened to such an extent that they can be easily pulled out by the handful The process has to be supervised very closely, as the skins decompose when left hanging too long The sweating process is used only to a minor extent in the United States

2 *Lime process* The skins coming from the slaughter houses are first washed in large tanks, allowed to soak, and then passed to the scrubbing machine, where yolk, dirt, and other foreign matter are removed. Most of the natural grease remains in the wool In the next step any pieces of fat and flesh adhering to the pelt are removed Then follows the most important operation of the process, the "painting" For this operation the skins are turned with the flesh side up and carefully painted with slaked lime The lime remains on the skin overnight during which time it enters the pores of the skin, loosening up the wool roots The next morning the skins are given an additional cleaning to remove the lime, after which they are taken to the pulling room This process, which succeeded the sweating process, is the method employed in the United States and Australia in recent years The wools pulled by the lime process are also known as "slipe" wools The lime process has more recently been replaced by the faster and cheaper depilatory process

3 *Depilatory process* This process is described in detail since it is extensively used in the United States When a pullery is connected with a slaughter house, the killing of the sheep is done on the first floor and the pulling in the basement After the slaughtering, the skins are stripped from the bodies and transported by chute to the pullery The first operation is the washing process which takes place in large, semicylindrical wooden or metal tubs, and by which yolk, dirt, and other foreign matter are removed The skins are agitated by large wooden paddle wheels and a constant flow of fresh water carries the dirt away The washing time is approximately half an hour Then the skins are removed from the tubs and the liquid extracted in large centrifuges or hydro-extractors The moist skins are then taken to the paint room, where they are placed on flat tables with the wool side down The flesh side of the

Fig 7 Painting sheep pelt with depilatory *Courtesy Eavenson and Levering.*

skin is then painted with the depilatory solution composed of water, sodium sulfide, and lime (Fig 7.) The strength of the depilatory varies with the character of the skin and the season of the year Every part of the flesh side of the pelt should be painted, to cover all the pores which lead to the roots of the hair Special care has to be taken to prevent the depilatory from coming into direct contact with the wool, because serious alkali damage may result The skins are then folded once lengthwise and hooked through the head parts of the pelt on movable racks These racks are suspended from overhead tracks On these racks the painted skins remain approximately twenty-four hours to permit the depilatory solution to work through the skin and loosen the roots of the fiber. An older method of placing the skins in piles on the floor until the following day has the danger that the skins, as well as the wool hair, are likely to be damaged due to the heat which may develop when the skins are packed tightly and begin to sweat. At a high temperature the strong chemicals will react on the skins to such an extent that they will lose in value To avoid spoiling, a number of pulleries have refrigerated paint rooms After the storing time has passed the wool on most parts of the skin can, when brought to the pulling room, be easily removed by hand

Grading of Pulled Wool

All kinds of breeds of sheep are slaughtered and the pelts carry, therefore, the widest range of wools To get the largest returns for pulled wool, it is necessary to grade the wool according to fineness and lengths Therefore, the pelts are first graded in the pulling room The length of the fiber or pulled wool is governed by the length of time which has elapsed between the last shearing of the animal and its slaughter With lambs it is the time which has elapsed from the birth to the slaughter Wool is classed according to length into clothing or combing. Practically all wools pulled from June to early November are clothing wools The pelts are now ready for the pulling.

The puller's function is twofold: he has to remove the wool from the skin and at the same time he has to sort the wool just as the wool sorter sorts fleece wools The puller starts his work by opening the folded fleece and placing it wool side up on a sloping table known as a beam He quickly pulls the wool from the skin by the handful, throwing it into wooden containers which are conveniently placed around him to receive the different sorts. (Fig 8) The wool from the head, tail, and shank part of the skin is usually removed with shears as the depilatory is not able to penetrate the heavier skin of these parts As soon as the wool has been removed, the puller folds the skin or slat, as it is now called, grain-side in, and places it on the floor behind him These slats are removed from time to time and stored in the cellar The pullers' work is piece work based on the number of skins which they pull It is customary in this country to sort into only four grades AA, A, B, and C AA represents, expressed in fleece-wool grades, fine or 64s and up A equals half-blood or 58s-60s B corresponds to three-eighths blood and one-quarter blood or 48s to 56s C covers all the grades from low-quarter down to braid The puller makes very few sorts from the skin, usually three from fine fleeces, two from medium, while coarse fleeces are thrown entirely into grade C The shortest wool is obtained from sheep sheared in the month before slaughtering It averages about one-fourth of an inch and is known as *shearling* When the receptacles are full they are emptied into piles at one end of the pulling floor for overlooking

Fig 8 Pulling and sorting wool

The overlooker is a skilled worker who removes all wool which does not belong in that particular grade After overlooking, the clothing wools are run through a picker for the purpose of blending and opening up the wool previous to the drying Combing wools are normally not run through the opener As the painting and pulling is done when the wool is in moist condition it has to be dried before it can be packed From the pulling floor, therefore, the wool is dropped through a chute into the feeder of a regular loose-wool dryer After coming from the dryer, it is transported to the packing

machine New burlap bags are suspended in holes in the floor, hanging over the floor below. The wool swept into this bag is compressed by an automatic plunger When the bags are filled they are sewed together and dropped to the floor below. They are weighed and stored according to the grades of wool they contain. The bags vary from 150 to 200 pounds in weight

Where the slaughter houses are not connected with pulleries arrangements must be made for preserving the skins of their slaughtered sheep until they can be pulled. This preservation is done in two ways, salting and drying. Salting is more satisfactory from the puller's standpoint but preserves the skin for only a limited time The skins are laid flesh side up on the floor, smoothed out and covered with salt Several rows of skins are laid one on top of another. The time for proper curing is from three to four days After that they can be shipped to the distant pulleries The puller has to soak the skins for at least twenty-four hours before a regular washing process, for the purpose of softening them and removing the salt.

When the skins are kept for weeks and months or have to be shipped long distances by water, for example, from Australia to the United States, they are dried thoroughly in the open air by sun and wind. Then they are compressed into bales and shipped to the pulleries. When these dry skins reach the puller it is necessary to soak them for several days before they are soft enough for further processing. From the tanners' point of view the dried skins are just as good as the fresh skins

In Philadelphia large quantities of foreign skin, received in the dry state, are pulled. Gloversville, Johnstown, and New York also import large quantities of sheep and goat skins primarily for the production of leather for gloves

These skins come mainly from the Union of South Africa, northern Africa, Spain, the Balkan states, Turkey, and China The wool is of very low grade, often 100 per cent kemp hair.

Marketing of Pulled Wools[4]

The wool merchant plays no important part in the marketing of pulled wool. The large packing houses sell their pulled wool under their own names or have formed subsidiary companies to handle their wool. Therefore, the majority of the mills using pulled wools purchase them directly from the pulling houses Over 50 per cent

[4] C M Allen, *Extracts from Lectures on Wool*, Boston University

of the pulled wool market is in a scoured condition which means that the pulling houses scour large quantities themselves. The wools of combing length are always sold in the grease The shrinkage of this wool due to the scouring of the skin before pulling is much less than the shrinkage of regular fleece of the same grade The approximate shrinkages for the various grades are as follows: AA, 35 per cent; A, 25 to 33 per cent, B, 12 to 20 per cent; C, 15 to 25 per cent The prices usually range from 5 to 15 per cent less than similar fleece wool, depending on the market. The main ceiling prices set up for pulled wools during World War II are given in Table 6

TABLE 6

MAXIMUM PRICES OF DOMESTIC PULLED WOOL, 1945–46

Grade	*Length (over)*	*Price Pulled*	*C.C.C. Selling 1946*	*Grade*	*Length (below)*	*Price Pulled*	*C.C.C. Selling, 1946*
70s	2 in	$1 22	—	—	-	—	—
64s	2½ in	1 20	$1 03	64s	1½ in	$1 12	$0 90
62s	2½ in	1.18	1 01	—	—	—	—
60s	3 in	1.16	1 00	60s	1½ in	1 07	0 88
58s	3 in.	1.12	0 95	58s	2 in	1 04	—
56s	3½ in	1 08	0 93	56s	2 in	1 00	0 80
50s	4 in	1 02	0 90	50s	2 in	0 92	—
48s	4 in	0 98	0 78	48s	2 in.	0 93	—
46s	4 in.	0 94	—	—	—	—	—
44s, 40s, 36s	4 in	0 92	0 73	—	—	—	—

Foreign pulled wool The world's leading wool pulling center is Mazamet, a small city in France In Mazamet the bulk of the wool skins from Australia and South America are pulled by the sweating process. Other countries which played a part in the prewar pulled-wool market are Germany and Austria, which purchased their skins from Russia, Turkey, the Balkans, India, and China

Uses of Pulled Wool

Uses of pulled wool are just as varied as those of shorn wool The clothing lengths are used by most woolen mills for the manufacture of the lower grades of woolen goods, where it is used in various percentages in connection with noils, reworked wools, cotton, and rayon The finer grades have a wide call among blanket manufacturers The combing wools are seldom combed in the top

by themselves They are blended with fleece wool. They are also very suitable for producing knitting yarn as well as for the manufacture of paper-makers' felts In regard to its general quality in comparison with fleece wool, pulled wool is considered inferior to fleece wools because the root of the fibers are more or less damaged by the chemicals used Through this damage the affinity for dyes is changed and the result is uneven dyeing. In this respect the wool pulled by the sweating process is superior. Pulled wool is easily identified, as illustrated in Fig 9

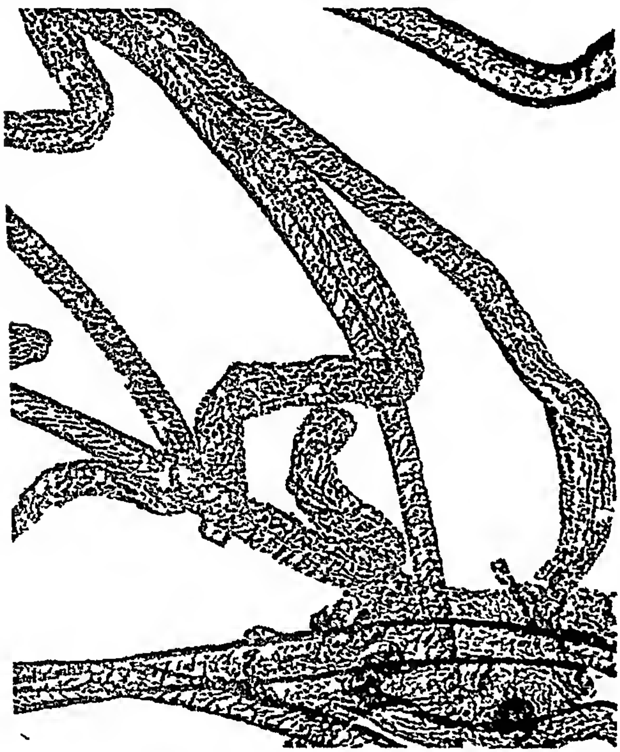


Fig 9 Pulled wool showing root ends (X160)

FUTURES TRADING IN WOOL AND WOOL TOP CONTRACTS

E. A. BEVERIDGE

Futures contracts are legally binding obligations They may be considered a special kind of spot or cash contract Trading in futures is a recognized and well-established function of organized wool and wool top exchanges in the United States and other countries

There are two types of futures contracts in this commodity, namely, wool top futures and wool futures The wool top is wool that has been scoured, carded, and combed; in other words semi-manufactured It is in the form of a ball of about 8 or 9 pounds These balls are packed in bales of about 250 pounds each Wool futures, on the other hand, contract for the delivery of wool in the grease, or in an unprocessed form

From about 1888 to the beginning of World War I, trading in wool top futures was actively carried on at Roubaix-Tourcoing, France and at Antwerp, Belgium The former market reopened in 1922 and the latter in 1929, but both closed with the outbreak of World War II Trading in wool top futures was reinaugurated on May 18, 1931, and in wool futures on March 17, 1941, on the New York Wool Top Exchange (known formally as the Wool Associates of the New York Cotton Exchange) Despite difficulties caused by World War II, both markets have been in continuous operation

Operation of the New York Wool Top Exchange

Membership New York Wool Top Exchange memberships fall into two classes.

Class A. Members of the New York Cotton Exchange automatically become Class A members of the Wool Associates A few wool people have Class A membership which they have obtained through becoming members of the New York Cotton Exchange Only Class A members can execute futures contracts in both wool and wool tops or carry them for account of others

Class B The number of Class B members is limited to 150 There are now about sixty-six such members, mostly people in the wool industry They, like those Class A members who do not clear their own transactions, are charged rates of commission half of those charged to nonmembers

Wool top futures contract The wool top futures contract calls for the delivery in an approved warehouse in greater Boston at the contract price, of 5000 pounds of Exchange Standard tops during the calendar month named This standard or basic grade is an American fine wool top, conforming to U S standard 64s, made from merino wool, oil-combed, containing not over 3 per cent of fat and oil, and produced from wool shorn from live sheep in the United States Tops made from wool or blends of wool grown anywhere in the world which meet this standard, with pulled wool permissible to the extent of 20 per cent, may be delivered Dry-combed tops are deliverable at a premium determined as provided in the Exchange by-laws - Tops are appraised by official inspectors at percentage premiums over, or discounts under, the basic grade value For example an 80s good staple top receives a premium of 2 per cent No top more than 8 per cent inferior to the standard

may be tendered and tops valued at over 3 per cent receive no more than a 3 per cent premium. No top may be delivered that contains over 4 per cent of oil and natural fat.

Wool futures contract The wool futures contract calls for the delivery in an approved warehouse in Greater Boston, at the contract price, of 6000 pounds, clean weight, of the Exchange Wool Standard or basic grade, which is a 64s quality graded wool shorn from live sheep in the United States, the wool being about 2½ inches average stretched length and of good color. Acceptable types of wool of average 60s or finer grade, meeting U. S. standard, grown anywhere in the world, are deliverable Pulled wool is deliverable only if uniform in grade, staple and character and if it comes from the main body of the skin Blends of wool are deliverable but only if of similar character and as accepted by trade custom Blends of wool from countries other than the United States, and blends of pulled and shorn wools, however, are not deliverable

Wool is graded by Exchange inspectors at percentage premiums over, or discounts under, the standard No wool lower than 6 per cent discount may be tendered. The highest premium payable is 6 per cent. Wool is delivered in the natural or grease state, although the price is quoted per clean pound

Commissions. In both wool and wool top contracts the rate of commission to buy or sell is $15 for nonmembers and $7 50 for members residing in the United States or Canada. Residents of other countries pay $1.25 more. Such commission charges are the only ones incurred when a purchase is liquidated by a later sale, or vice versa

Trading Delivery is made by the tender of a warehouse receipt, and also Exchange weight, grade, and other certificates Five business days' notice of such delivery must be made by the deliverer In both wool and wool top contracts the seller has the choice of the day of delivery during the delivery month, and of the quality to be delivered, provided it is within the contract requirement. All trading in futures is done on margin since title cannot pass until delivery is made, which obviously must be in the future. The full value is paid when delivery is made The margin required varies with the state of the market, with a minimum being set by the Exchange At the present time a margin of $750 per contract is generally required by carrying members In wool and wool top futures trading no credit is permitted, even to trade accounts

As in all futures markets, trading is confined to certain hours (in wool · 10·10 A M to 2 40 P M.; in tops · 10:20 A.M to 2·50 P M) and to a designated area on the Exchange floor At the close of the day all transactions in futures are cleared through the New York Clearing House which simplifies considerably the process of liquidation A purchase of futures is liquidated either by receipt of the commodity, or by sale of the same future made, prior to delivery, through the same broker A sale of futures is liquidated either by delivery of the commodity, or by the purchase of a contract for the same delivery month made through the same broker, in other words, by an offsetting transaction The percentage of deliveries to total transactions is comparatively small Minimum spot fees in the case of deliveries are charged the client for the various services rendered, as well as a commission for the initial futures transaction It is only after delivery has been made that storage, insurance, interest, and other handling charges begin

Sales activity The activity of wool top futures trading may be gauged by the record of sales · 1,090 contracts in 1932; 14,879 in 1938, 32,256 (a record) in 1940; and 7,766 in 1945 In wool futures, the volume of sales has been decidedly smaller: 4,677 contracts in ten months of the first year (1941) (the highest) and 2,319 in 1945 Hindrances to uncontrolled activity in the postwar years have been · Commodity Credit Corporation purchase program, O P A ceiling prices, British control prices, and foreign exchange restrictions

Values and Services of Futures Markets

The futures market is of considerable economic value to the various sections of the wool industry It provides a central place where the bids and offers of producers, merchants, dealers, importers, manufacturers, and consumers can come together and thereby establish a broad and liquid market It establishes equitable rules and practices for the conduct of the wool business and for a speedy settlement of disputes, besides promoting the interests of the industry generally In addition, a futures market necessarily collects all available statistics and other data on wool for the benefit of its members and its members' clients

The futures market also serves in equalizing supply and demand, providing a means of discounting the future, helping the distribution over twelve months of a crop harvested in a few, and in pro-

viding an accessible market at any time during business hours Its greatest service, however, undoubtedly is in furnishing the industry a means of hedging its commitments, This use of the futures market by the individual in the various sections of the industry is discussed in the following paragraphs

1 The *wool grower* can make advantageous use of the futures market without interfering with his present method of disposing of his clip For example, he may note before the time of shearing that wool futures quotations are at a relatively attractive level, one at which he would gladly sell his wool if it were sheared and readily deliverable to the cash buyer. The futures market offers him an opportunity to capitalize on this situation Through a commodity futures broker he can sell a futures contract on the equivalent weight of his clip for July or some other suitable delivery date This sale, say at $88 clean basis, virtually assures the grower the price that he will receive for his drop, no matter what course the wool market should take thereafter

His next procedure would be to sell his clip to a cash buyer, at which time he would repurchase his sale of futures Suppose he had sold only one futures contract (6000 pounds) and the market had declined $08 from the $88 level He would then have made a profit of 6000 x $08 or $480, which could be applied to offset the corresponding decline in the value of the clip. On the other hand, if the market had advanced, say after the $88 sale, then there would be a loss in futures of 6000 x $10 or $600, which could, however, be offset by the probable advance of a like amount in the value of the clip If his wool is within the range of deliverable grades, he could deliver it against his futures sale All he would have paid out to obtain this assured price level would be the futures commission of $15, which is not a large fee for such an assurance

But the grower has still another means of profiting by the use of futures contracts Generally speaking, he is glad to accept the wool buyer's price when the latter comes to bid on the clip. Yet there are occasions when he feels that the price is too low and the market is likely to do better later Accordingly, he buys a futures contract at the time of selling his clip and holds this future until the price has advanced to the desired level, at which time he liquidates his long future

2 The wool *merchant*, the wool *importer*, and the wool *topmaker* can each use the futures markets for hedging purposes The general rule is to sell futures in an amount equal to the purchase of spot

wool If the prices of the spot and the futures markets move together, then it is obvious that the loss in the one offsets the gain in the other, and protection against a price decline in the spot article has been achieved However, it is obvious that the possibility of a speculative profit has at the same time been eliminated The operator, be he merchant, importer or topmaker, makes only his usual merchandising profit

An example of such hedging will demonstrate this more clearly Suppose a dealer buys a lot of wool, weighing 12,000 pounds clean, at $ 95 per clean pound, but is afraid of a price decline before he can sort the wool and find a buyer. To protect himself, he sells *two* futures contracts, calling for delivery some few months ahead, say December Assume that the futures contracts were sold at $ 90 Some time later, he has an opportunity to sell the spot wool at $1 00 per pound after December futures had advanced to $ 93 He decides to liquidate his position in both spots and futures He makes a profit on his spot wool of $ 05 per clean pound and a loss of $ 03 on his futures contracts, making a net gain of $ 02 per clean pound

Hedgers make their profit by rehandling the wool they purchase and making a premium on sorted grades and qualities Sometimes they profit by reason of a shortage of some particular quality which then demands a premium compared with the basic grade

Another hedging use by the merchant is to be noted when a topmaker, for example, has a chance to sell tops to a spinner for delivery a few months later Not having the required wool on hand and being unable to buy any quickly and, moreover, fearing that a price advance is imminent, he seeks temporary price protection by the purchase of a like weight of some distant futures contract This gives him time to look around for the wool (required to make up the tops sold by him) in order to acquire it at a relatively fair price When he thus buys the wool he needs, he sells out a corresponding amount of the futures he had bought If the two prices (spot and futures) have moved along parallel lines, then it is obvious that he has had price protection If the market advanced, he would gain on his futures and lose a corresponding amount on his spot sale The operation would leave him free from worry over market losses and enable him to devote his attention to the manufacture of the tops required If the market declined, he would lose when he liquidated his purchase of futures but he would be able, in general, to buy the spot wool at a correspondingly lower price

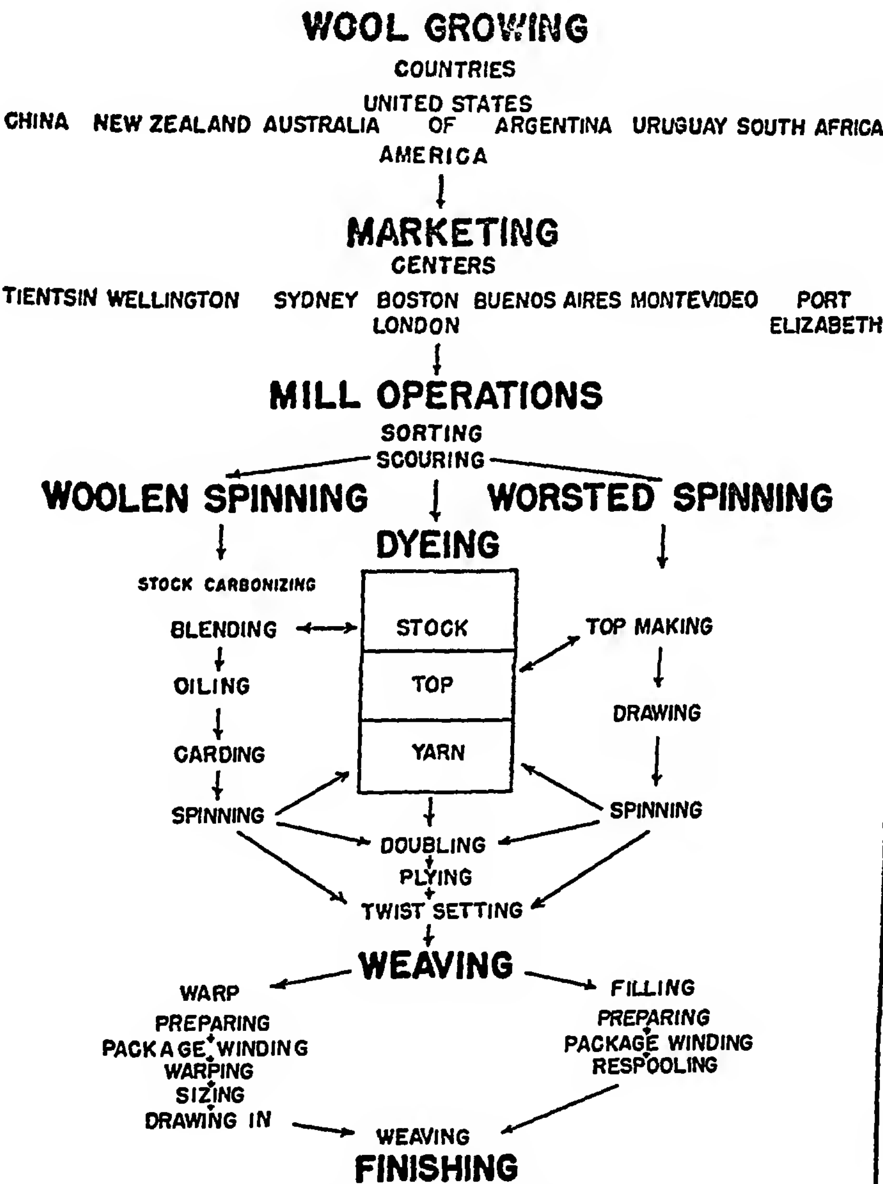
3 Both the *spinner* and the *manufacturer* can make advantageous use of futures in a manner similar to the procedures just described

Even the clothing manufacturer, the mail order house and the wholesaler can benefit by utilizing the futures markets for protection against broad price swings

4. Beside these three trade groups which use the futures market for hedging or other purposes, there is another group, the *speculators*, which use it as a convenient medium for speculation Speculators play an important part in the functioning of a futures market, for it is mainly they who assume the speculative risk of which hedgers in the industry wish to rid themselves.

The futures markets are not, of course, to be considered as substitutes for cash markets but as supplementary markets with additional possibilities

Bankers who finance growers, merchants, importers, topmakers, spinners and manufacturers generally grant better financial arrangements to those who try to minimize their inventory risks by hedging their commitments in the futures markets For both banker and customer, such hedging has reduced the previously existing speculative risk by transferring that risk to the speculator



FLOW CHART OF WOOL MANUFACTURE

Wool Sorting Room
(Courtesy Forstmann Woolen Co)

In New Zealand it is required by law that at least one-third of the packs used by wool growers be made from flax grown in the Dominion They are allowed to import jute packs only under government license These New Zealand flax packs are, according to reports from England, not entirely suitable and the New Zealand Government has made an agreement with the British Wool Federation that there will be no increase in the proportion of the flax pack to be used until the material is further improved

From the chapter on grading and marketing it was learned that wool varies considerably in regard to fineness and length according to the breed of sheep. In addition each fleece carries strikingly different qualities of wool No two fleeces even from the same type of sheep and from the same district are exactly alike in quality and quantity distribution If the manufacturer were to use the fleece in its original form, he could produce only medium or coarse yarns, and the resulting cloth would never be of the highest possible quality From this explanation it is obvious that, prior to processing, it is

TABLE 1 WEIGHT AND SIZE OF WOOL BALES AND BAGS

FOREIGN	*Average Weight in Pounds* Bag	Bale	*Size of Package in feet*
Argentina—B A—grease		1000	5 x 3 x 2½
Argentina—B A—scoured		700–800	5 x 3 x 2½
Asia		330	
Australia—greasy		330	3 x 2½ x 2½
Australia—scoured		250	3 x 2½ x 2½
Cape—South Africa—grease		370	[illegible] x 3 x 3
Cape—South Africa—scoured		210	[illegible] x 3 x 3
Cape—South Africa—mohair		300–350	3 x 3 x 3
Chile—grease		500–1000	3½ x 2 x 2
China		500	3 x 1½ x 1½
East India		330	3½ x 1½ x 1½
England—squares		700	4 x 3 x 3
England	500	500–600	6 x 4 x 4
Montevideo—grease		1000	5 x 3 x 2½
Montevideo—scoured		800	5 x 3 x 2½
New Zealand—grease		330	4 x 2½ x 2½
New Zealand—scoured		250	4 x 2½ x 2½
Peru—unwashed	230	800–1000	3½ x 2 x 2
Peru—scoured	180	180–250	3 x 2 x 2
Punta Arenas		500	4 x 3 x 3
Scotland—carpet	220–220	350–400	Long bags 6 or 7 long x 3 wide
Turkey		250–325	2½ x 2½ x 2½
Turkey—mohair		150–175	..
Spain—Pyrenean grease	200–250	.	..
U S S R	300–400		
Donskoi—carpet		500	4 x 2 x 1
Donskoi—unwashed		300	or
Donskoi—washed fleeces	200		3 x 1½ x 1½

DOMESTIC	Bag	Bale	Size of Package
California—grease		500	4½ x 2 x 2½
California—scoured		250	4½ x 2 x 2½
Indiana	175		6⅛ x 1½ x 2
Michigan	220		6⅛ x 1½ x 2
Montana—grease	325	.	6⅛ x 1½ x 2
Ohio	200		6⅛ x 1½ x 2
Oregon, eastern—grease	350–460	540	6⅛ x 1½ x 2*
Oregon valley—grease	350–460	475–520	6⅛ x 1½ x 2*
Territory	350–460	475	6⅛ x 1½ x 2†
Texas	210	.	5⅛ x 1½ x 2
Utah—grease	325	.	6⅛ x 1½ x 2

* If baled, same as California
† 2½ x 2½ x 4 in bales

necessary to divide the fleeces or pieces into their respective spinning qualities so that they may be used for different grades of cloth The operation of dividing the wool from each fleece into the different sorts or grades is called *wool-sorting*, while the person who performs the operation is known as a *wool-sorter*.

WOOL-SORTING

Wool-sorting is, therefore, the first process which grease wool undergoes after it is purchased by the manufacturer The sorts are made according to fineness, length, soundness, color and amount of vegetable matter This places all the fibers with equal character into one group, enabling the manufacturer to produce out of this sort the yarn or fabric for which it is best suited

It is important to note that all whole fleeces in each bale have previously been classed or graded This means that there is a great deal of difference between classing or grading of fleeces as a whole and opening and sorting them into subsorts Sorting is a more advanced step, requiring more technical skill. A qualified wool-sorter is always a reliable wool-classer, but a wool-classer is very seldom a good wool-sorter.

As previously stated, sorting is guided by the requirements of each manufacturer and differs according to the type of yarn and cloth to be produced from the wool A mill manufacturing high-quality goods will always make as many sorts as possible to get the full benefit of each fleece, whereas mills running lower grades of goods may make only two main sorts by throwing out the edges of the fleeces only. In other words, the higher the quality of the goods to be manufactured the more carefully the sorting is done The general tendency in the United States is to do less and less wool-sorting, since the operation is done by hand and is necessarily slow and expensive It is estimated that over 75 per cent of the wool consumed in the United States is "trap-sorted." The latter means that very little is removed from each fleece apart from low ends, tags, and britch

Wool-sorting is a trade learned only by long, practical experience In European countries, where special care is taken with sorting, a four-year apprenticeship is required The wool-sorter does the work by observing and handling the wool and his experience enables him automatically to assign to each its proper grade Celerity in decision (the first impression is generally correct), sensitive touch, and good eyesight are essential requisites for a wool sorter A north light is necessary, experience has shown that poor illumination causes the

sorter to grade the wool too fine and in direct sunlight the wool appears coarser to the sorter It has been established by English scientists that a psycho-physical law (Fechner-Weber law) is the fundamental basis for wool-sorting, and that the eye, in the visual sense, rather than the touch, is the paramount factor.

Bench-Sorting

The wool bales obtained from a warehouse are weighed and a record is made of each lot number and bag number To assist the proper opening of the tightly wrapped fleeces, in many mills the bales are subjected to a heat-treatment, particularly in winter In cold temperatures wool grease solidifies in the fleeces and renders them stiff and difficult to open This heat-treatment is given in an ordinary hotbox (120° F), where the wool is stored for as long as twenty-four hours, depending on the size and compactness of the bales

One bale at a time is taken up and placed conveniently near the sorter's working table Each sorter has a bench approximately 7 to 10 feet long and 3 to 4 feet deep, the center of which is covered with wire screen or wooden lattice work This arrangement permits loose

Fig 1 Wool Sorter at Work—Bench Sorting
(*Courtesy Forstmann Woolen Co*)

dirt and sand to fall through during the sorting The tables are arranged in front of a row of windows facing north, or in the center of a room with specially placed skylights The wool-sorter is provided with a number of large baskets or box trucks on either or both sides, according to the number of sorts he is making He is provided with a pair of shears for clipping and cutting the strings with which domestic fleeces are tied together

The sorter opens the bales by cutting the burlap and rolling the bale on its side He removes several fleeces at a time and places them on his table The fleece (as noted in the chapter on marketing) is rolled together in a definite manner into a tight bundle, held together by a paper string (domestic) or by a twisted portion of the fleece itself (imported) In fact, most Australian fleeces are not tied at all In case the fleeces are tied with strings, it is advisable to cut the strings of fifteen to twenty fleeces on the floor The strings are collected in a bag for later disposal After opening a fleece the sorter shakes it over the screen of the table, thereby ridding the fleece of

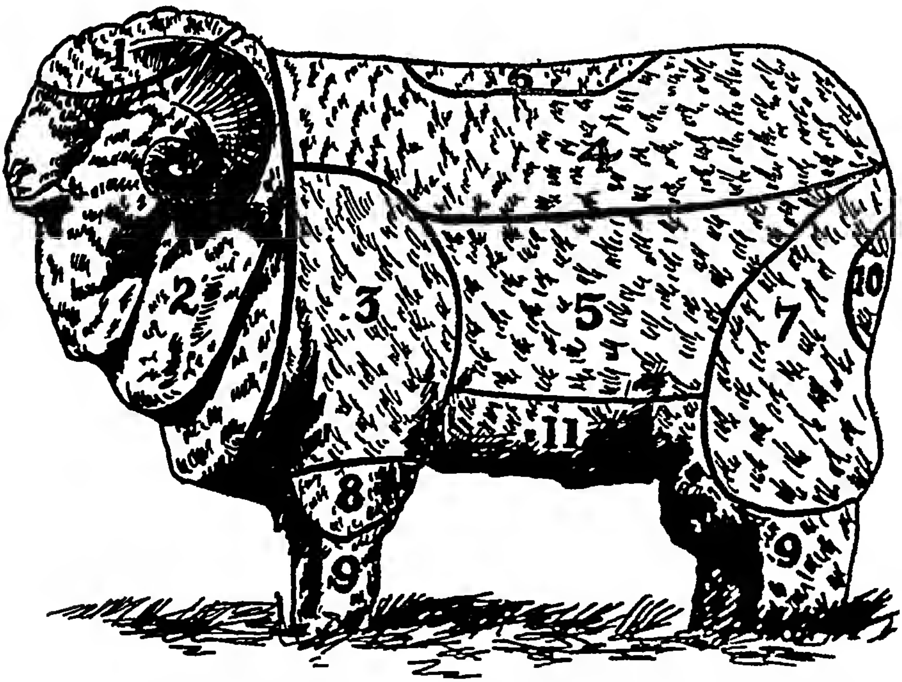


Fig 2 Parts of the sheep that furnish the different sorts of wool

the loose dirt, sand, straw and other foreign matter When the fleece is completely spread out and the various parts noted, such as head, tail, and side, he commences to "skirt" the fleece Figure 2 is a drawing of a merino sheep which shows the parts of the animal's fleece that furnish the different sorts. According to Smith[1], the names of these parts and the type of wool prevailing in the part are as follows:

1 *Topknot* Very light, short, moity, and inferior wool
2 *Neck wool* Very light-conditioned and long-stapled wool, the folds also contain coarse, matted lumps of inferior wool
3 *Shoulder wool* The best wool grown by the sheep Sheep judges usually take the shoulder wool as a standard and see how the wool on the other portions of the sheep compare with it
4 *Fleece wool* Good average fleece wool, usually free from all vegetable matter.
5 *Brisket wool* Similar to shoulder wool (No 3), usually a little heavier in condition
6 *Back wool* Inclined to be open and musky
7 *Britch wool* Coarser wool than the other portions of the fleece and in many cases inclined to be kempy, the wool is also matted with burs or seeds
8 *Arm piece.* Very short wool surrounded by fribby edges; burs or seeds collect heavily on this portion of the fleece
9 *Hairy shanks* Hairy or kempy fibers containing very little wool; they are used for the manufacture of low-quality goods such as cow or horse rugs when blended with other wools
10 *Stained wool* Wool that will not wash white, and is very heavy in condition (Stained wool from ewes should always be dried before baling)
11. *Belly wool* Good bulky wool, heavy in condition, and usually very burry or seedy.

Generally speaking, the best wool is that which comes from the shoulders and sides of the sheep. Next in order of value is wool from the lower part of the back, the loin, and the upper part of the legs Wool from the neck, britch, belly, chest, head, throat and lower part of the legs is all inferior When the fleece is deeply skirted (undesirable parts and stained portions removed) before being shipped to market, as is customary in Australia, practically all of this inferior wool is already removed A light skirting may leave a certain amount of it in the fleece, while an unskirted fleece contains all of it (See

[1]Smith, Henry B *Sheep and wool industry of Australia and New Zealand*, rev 3r ed.

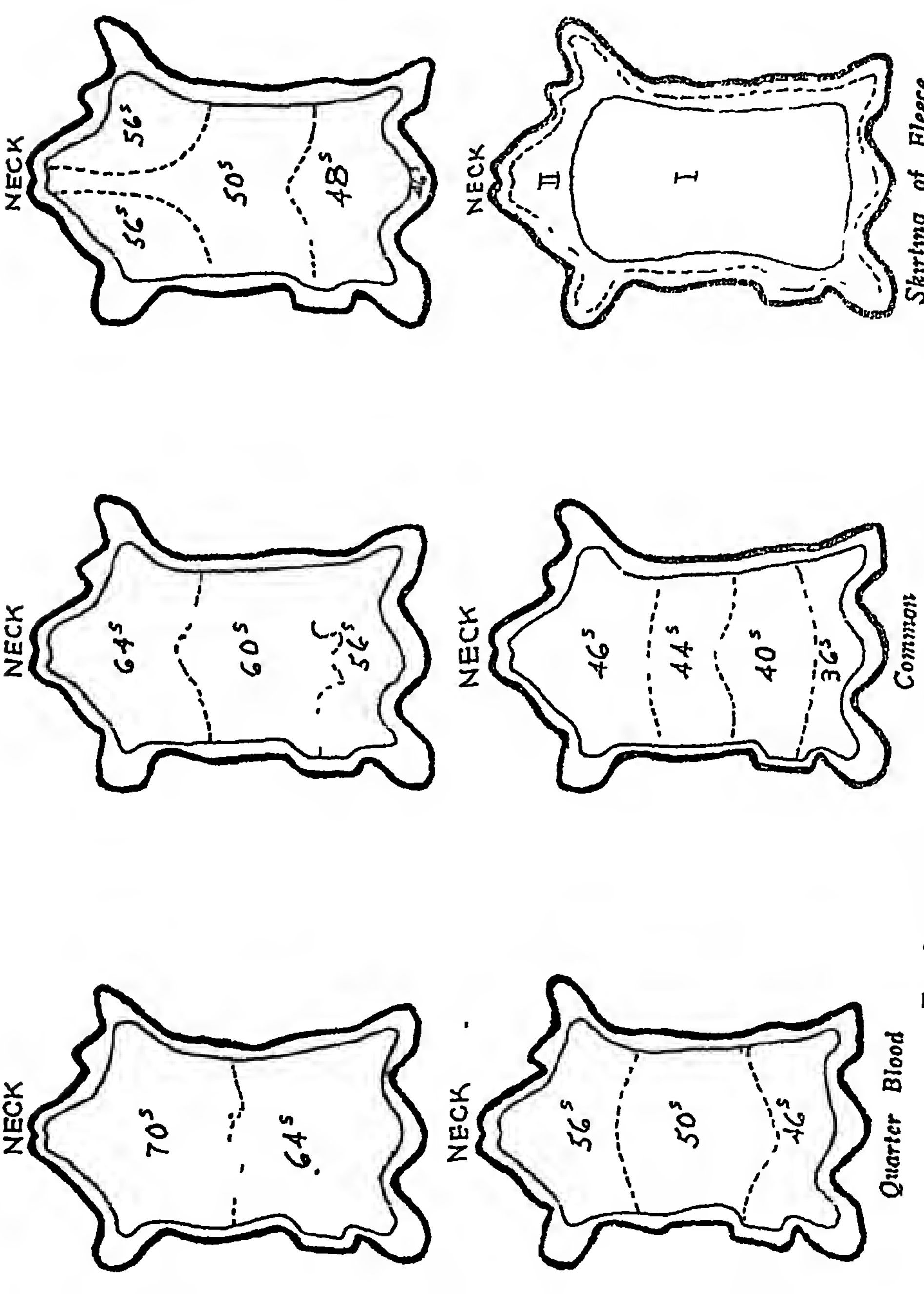


Fig 3 Diagrams of sorts represented in various wool fleeces

Fig 3) Apart from the rough classification just given, the wool-sorter has no guide except his own judgment and his familiarity with the manufacturer's requirements In sorting for a quality, the wool-sorter sets up a limit as to the finest and the coarsest staples that can normally go into the making of that quality. He may have at hand a standard sample, which was selected by visual inspection, for use as a guide

The sorter first removes the britch and the stained belly parts of the fleece which he throws into a basket intended for this sort. Working inward from the edges he tears out various sections by hand and places them in separate baskets according to the different sorts he has to make In addition, the sorter removes from the fleece staples carrying dried branding material such as paint and tar and all lumps, twigs, dirt, matted fiber, large burrs, and other roughage that can be removed without too much expenditure of time Staple carrying branding marks is clipped by hand to save as much of the wool as possible

After the sorter has filled several baskets of the main sorts, these baskets are taken to the foreman, whose duty it is to inspect each sort separately over a sorting table He takes out any pieces which are either too fine or too coarse for the quality in question. Each backet is then weighed, recorded, and emptied through a trap door in the floor to the storing bins.

TABLE 2 APPROXIMATE COMPARISON OF WOOL GRADES USED IN THE UNITED STATES

	U. S Domestic	*English*	*French*	*German*	*U S Pulled*	*Approx Microns*
Fine	80s	80s	—	AA	AA	19 0
Fine .	70s	70s	110	A	AA	20 5
Fine .	64s	64s	105	AB	AA	22 0
	62s	—	PM	—	A	23 0
Half blood	60s	60s	PC	B	A	24 0
Half blood	58s	58s	I	C^1	A	26 0
	—	—	II	C^2	—	27.5
Three-eighths blood	56s	56s	—	—	B	28 5
			III	D^1	—	29 0
Quarter blood	50s	50s	IV	D^2	B	31 0
Quarter blood	—	48s	V	E^1	B	33 0
Low quarter blood .	—	46s	VI	—	C	35 0
Common	—	44s	—	E^2	C	37 0
Braid .	—	40s	—	—	C	38.5
Braid .	—	36s	—	—	C	40 0

Each mill designates its sorts by a system of numbers, letters, or terms The terms may or may not be different from the standard wool terms for the sorts In parts of the east, where the founders of the woolen mills were of European origin, many of the European terms have been retained In the Lawrence district the English terms are employed, whereas in Woonsocket the French and in the Passaic district some German designations are still used

Numerical designations are also used as, for example fine sorts =12s, half blood=10s, three-eighths blood=8s, quarter blood=6s, and low quarter blood=5s Because of the variety of designations the wool-sorter in the average mill knows the various grades of wool only by the system of designation used in that mill

Table 2 illustrates the various designations for wool sorts used in the United States and their approximate relationship to each other

One example of two typical mill sorts, showing the percentages of the various grades, sorted from two invoices, is given in Table 3

TABLE 3

COMPARISON OF AMERICAN AND AUSTRALIAN WOOL SORTS

	Original 12-Month Texas (40,000 Lb)			*Australia (30,000 Lb) 64s Combing*
Sort	*Warp Above 1½"*	*Filling Below 1½"*	*Total Per Cent*	*Warp Only, Per Cent*
Loss in sorting	—	—	5 0	2 8
80s	1 4%	0 97%	2 27	0 22
70s	17 56	5 52	23 08	21 42
64s	41 02	20 68	61 70	65 02
60s	2 76	—	2 76	10 15
58s	0 13	—	0 13	0 07
40s	0 03	—	0 03	—
64s burry	—	—	1 10	p 30
Black	—	—	0 09	—
Felted	—	—	0 03	—
Paint	—	—	0 08	0 02
Stained	—	—	3 29	0 005
Strings	—	—	0 56	—

Trap-Sorting

In contrast to bench-sorting as just described, 75 per cent of the wool in the United States is trap-sorted This is a much quicker but cruder way of sorting In trap-sorting there are usually three tables feeding into one trap The tables are placed in a radial position to the trap Four men or boys work at each table· two of them open

the bales by cutting the straps or bands, one does the sorting and the other the checking or overlooking.

Trap-sorting is practiced in the United States because the intense competition among top-makers and spinners has made imperative the elimination of the added expense of bench-sorting. In trap-sorting a much larger production can be attained. The production in sorting depends entirely on the mill requirements. In the best of bench sorting an average hourly production runs from 100 to 300 pounds for fine wools, amounting to 900 to 2,500 pounds in an eight-hour day. The slowest sorting is on the fine domestic wools, because much time is lost in proper skirting.

TABLE 4. COMPARISON OF TABLE-SORTING AND TRAP-SORTING
Example: Original 12-Month Texas (156,000 lb.)

Table-Sorted Wool		*Trap-Sorted Wool*	
80s	6.0%	80s	...
70s	23.5%	70s	
64s	57.3%	64s	87.0%
Off sorts	8.0%	Off sorts	8.8%
Loss	5.2%	Loss	4.2%

Occasionally wool sorters are attacked by a disease called anthrax, which is caused by a bacillus carried in the dust of certain wools. The worst wool for producing wool-sorters' disease has been found to be Van mohair. Other wools that are liable to be infected with the anthrax bacillus are Turkey mohair, Asiatic carpet wool, alpaca, camel's hair, and the wool of the cashmere goat.

Impurities in Grease Wool

Since scouring is essentially a chemical process, the complexity in composition of the raw material and the existing variations from type to type in various wools should be understood. These differences are contributing factors to the establishment of the scouring procedure. Tremendous shrinkage variations are encountered in the various grades, ranging from the fine- to the coarse-wool grades. In addition, significant differences in shrinkage and the chemical nature of the impurities exist within each of the grades; these are attributable to differences in breeds, environment, climatic conditions, and feeding habits. For the most part, these impurities may be divided into three broad categories: (1) natural impurities, (2) acquired impurities, and (3) applied impurities.

1. The *natural impurities* include the various oils and fats secreted by the sebaceous glands in the animal's skin, referred to as *wool fat*, and the water-soluble salts from dried perspiration, which are designated as *suint* Together, these two basic constituents comprise the *yolk* The composition of the wool fat varies considerably in the various wool types and breeds Essentially it is a mixture of higher fatty alcohols and fatty acids The physical and chemical characteristics of wool fat, such as its relatively low melting point and high capacity for emulsification, facilitate its removal from the wool fiber during the scouring process The free fatty acid content of the raw grease ranges from 2 to 15 per cent, providing, with the alkali used therein, the raw material for the manufacture of natural soaps during the scouring process. The *suint* is composed of the potash salts of the various lower fatty and amino acids derived from the decomposition and evaporation of protein materials and small percentages of inorganic salts such as potassium chloride and sulfate These salts may be removed from the wool by warm- or cold-water steeping They have excellent surface-active and colloidal-suspending properties that may be utilized in scouring Aqueous solution of these salts may be either slightly acid or alkaline in reaction.

2 The *acquired impurities* include sand, dirt, burs, pollen, and other forms of vegetable matter picked up by the sheep from its environment The heavier particles of vegetable matter may be removed to a slight extent by a mechanical dusting operation or by a preliminary steeping; however, the wool grease which surrounds the fibers acts as a binder for the more finely divided particles and holds them tightly on the fibers The vegetable matter must be removed either mechanically in subsequent mill operations such as bur picking, carding, and combing or chemically in carbonizing

3 The *applied impurities* consist of tar, pitch and paint which are used in small quantities for identification purposes, or chemicals which are utilized as preventives of, or treatments for, disease The

TABLE 5 PERCENTAGE VARIATIONS IN COMPOSITION OF GREASE WOOLS

Type	*Grease* %	*Suint* %	*Dirt* %	*Vegetable Matter*, %	*Shrinkage* %
Fine	10–40	2–20	5–40	0 5–2 0	30–70
Medium	5–20	2–20	5–20	1 0–5 0	20–50
Long	5–10	2–20	5–10	0 1–2 0	10–30
Carpet wool	5–10	2–20	5–20	0 5–2 0	20–40
Hairs	2– 8	1– 3	5–20	0 1–1 0	15–30

former are virtually impossible to eliminate through soap and alkali scouring, so it is common practice for these tips to be cut or sorted out of the fleeces prior to scouring

The variations and ranges in shrinkage and ratio of impurities as they occur within the various wool types are shown in Table 5

DUSTING AND OPENING

The removal of impurities from the raw wool by the detergent process is accomplished through the continuous scouring train This machine is a natural transition from the old hand-scouring and scouring-in-stationary-vat methods Numerous differences are found in the setup, type, size, and construction of machinery in various mills, according to types of wools scoured, production requirements, and various technological factors Generally, the machinery employed in the scouring process begins with some sort of mechanical opening-and-feeding equipment by which some of the heavier lumps of dirt and sand particles are shaken from the wool, effecting an opening of the clumps of fibers into individual staples and, at the same time, delivering a uniform quantity of opened stock to the scouring train This facilitates the proper penetration of the scouring liquor into the wool fiber, rendering the scouring more uniform and thorough In addition, the dusting accounts for a considerable saving in soap and alkali, as well as in scouring liquor Two types of dusters are in use the square duster and the cone duster

Square duster or opener Combing wools are generally run through

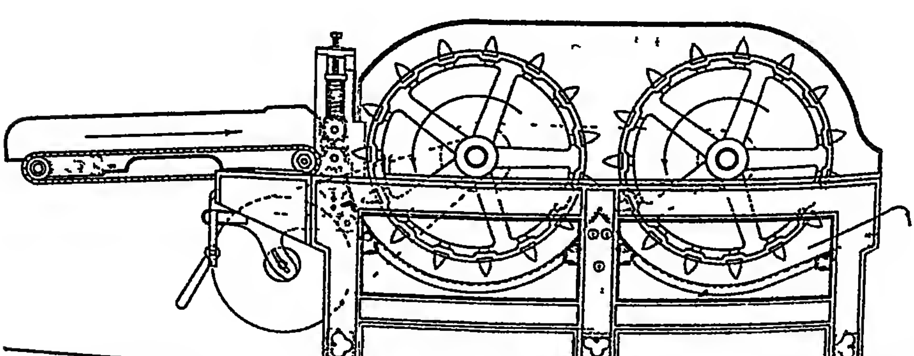


Fig 4 Double-cylinder wool opener *Courtesy C G Sargent's Sons Corp.*

a double-cylinder opener This machine (Fig 4) gives maximum fiber subdivisions and dirt removal with a minimum of broken staple The machine is built with either one or two pairs of feed rollers, and with or without a fan The principle of the double-cylinder opener is simply to beat the wool by means of two rotating cylinders against screens suspended below them There are two fifteen-lagged, toothed cylinders, each running in a downward direction, the first at a speed of 390 and the second at 450 r p m The grease wool is beaten by these cylinders against the underscreens and gives up a large amount of animal, vegetable, and earthy matter The machines are built in widths of 36 and 48 inches and are practically all metal

Cone duster These are principally used for dusting and opening especially dirty, long, and coarse wools and hairs such as mohair and camel's hair The operating principle is the same as that of the square duster The wool is beaten by a cone-shaped rotating cylinder against a screen suspended below it The cylinder is built up on a central shaft with arms attached to which are four wooden lags Each lag carries iron teeth that project 3 to 4 inches In many instances similar teeth are placed on the frame of the machine, so that the teeth on the main cylinder will mesh with them In order to carry off the light foreign matter and dust from the wool, a fan is used on top of the machine A screen beneath the fan retains the wool but allows the dust to be removed

The dusted wool is conveyed by blowers, conveyors, or trucks to the feed end of the train To allow an even and continuous supply to the train, feeders or hoppers of various types are employed

The *feeder* consists of a hopper box with an apron moving horizontally toward a spiked apron running vertically at a controllable rate of speed The spikes of this apron pick up small and large bunches of wool, which are combed off into small evenly distributed layers of wool by a large oscillating comb or *doffer* A brush on the opposite side of the apron, revolving in the opposite direction, knocks the wool off the apron directly into the first scouring bowl or via a blower or conveyor The feeding of different types of wools may be regulated by the adjustment of the position of the doffer, the control of the speed of either apron, or by varying the pressure of the wool against the spiked apron Here again, there is no standardization of equipment used by various mills for opening and feeding devices In many cases, such as heavy, lime-pulled wools, passage through twin dusters makes a tremendous difference in the effectiveness of the scouring Furthermore, a uniform delivery is of

primary importance in attaining efficiently and uniformly scoured wool

WOOL-SCOURING

The removal of the impurities present in raw wool is one of the most intricate and important operations in the manufacture of woolen and worsted materials The intricacies of the process are magnified by the widely divergent procedures advocated by the many wool scourers throughout the industry The importance of scouring to the manufacturer is attested by the manifold difficulties and problems which may be met in subsequent operations such as dyeing, carding, combing, drawing, spinning, and even finishing processes, that are attributable to improperly or over-scoured wool In judging the efficiency of the scouring process, the most critical factors are minimum scouring cost, maximum production and highest quality in the resultant scoured product With the present pressing demand for maximum production under existing mill conditions, rule-of-thumb, non-scientific methods of scouring control will certainly prove inadequate

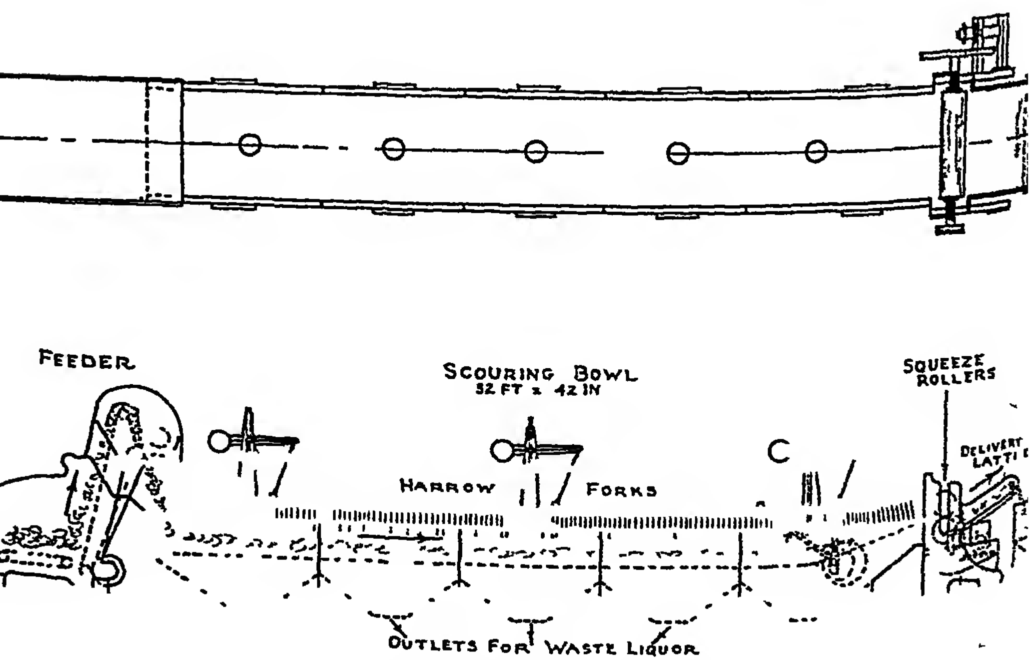


Fig 5 Feeding end of a continuous scouring train

The scouring of grease wools is accomplished, for the most part, by two processes (1) the soap-alkali process, (2) the solvent process Nearly 90 per cent of the wool processed in the United States is scoured by the use of alkaline detergents Various technological and operational difficulties have prevented the solvent process from attaining widespread application, despite its acknowledged advantages in both physical and chemical condition of the scoured product

The Continuous Scouring Train

The actual scouring operation is accomplished in a series of individual vats or bowls through which the wool is propelled by mechanical rakes with intervening squeeze rollers The final phase of the scouring operation is drying the scoured stock, for this purpose, specially constructed dryers are utilized so that the wool is delivered to the succeeding operations with the desired moisture content (See Fig 5 and Fig 6)

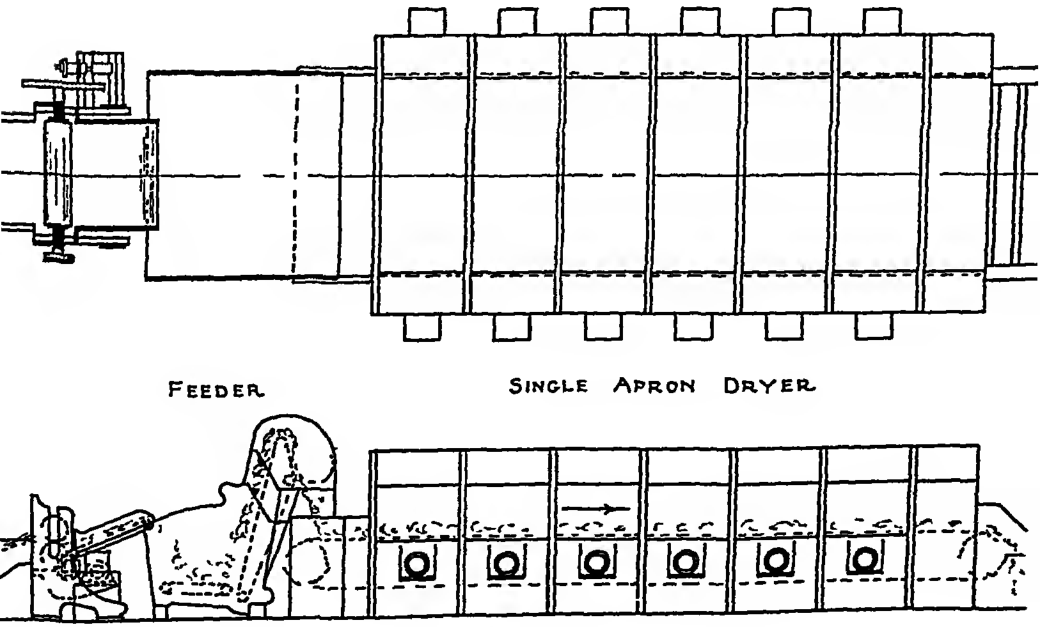


Fig 6 Drying end of a continuous scouring train

The number of scouring bowls comprising a single train varies from three to six, depending upon the type of wool scoured and the production required The sizes and capacities of the individual bowls, as well as their respective order in the train, may determine the scouring procedure, and vice versa Generally it is necessary to adapt the procedure to the number of bowls comprising the train and the type of wools scoured A three- or four-bowl scouring train has been found to be adequate for handling carpet or low-grade wools A four- or five-bowl line is most suitable for use in mills scouring medium and fine wools for their own consumption, whereas, in commission scouring, where facilities are required for bleaching and bluing, five or six bowls are deemed preferable In mill scouring, it has been proved that excellent production and quality scouring may be achieved with a four-bowl train

An inventory of wool-manufacturing equipment in the United States, taken by the Bureau of Census in 1943, showed that there were 384 scouring units available Of these, 227 were found in woolen mills and 157 in worsted mills Those in the worsted plants were further broken down according to the number of bowls making up a train, and it was found that there were twenty three-bowl units, seventy-five four-bowl units, fifty five-bowl units, and twelve others of various types

The scouring bowl itself consists of a rectangular-shaped vat or tank assembled in sections Scouring bowls are made in four different widths—24-inch, 36-inch, 48-inch, and 72-inch The 36-inch and 48-inch washers are used most widely and they are generally utilized in 16 foot, 21 foot, 27 foot, and 32 foot lengths Each bowl section is comprised of a 30- to 60-degree tapered sump or hopper bottom equipped with a valved draw-off outlet. These sumps permit rapid draining of the bowl contents and the steep pitch of the walls allows settling of the dirt particles from the scouring liquors About 1 foot below the surface of the scouring liquor in the bowl is a false bottom of fine mesh copper or stainless steel screening over which the wool is passed and through which the heavy sediment may settle into the sumps.

In American-built machines, the wool is transported through the bowls by the action of the harrow forks, a single unit of which is a series of parallel rakes set about 12 inches apart and operated on an off-center cam A positive sweep of the rake propels the wool from 12 to 16 inches forward in the bowl Although this rake is in constant oscillation, there is a minimum of agitation, which

would create a felting action on the fibers At the front end of each harrow fork the rakes are provided with a perforated screen immersion box or ducker which, upon entrance into each bowl, serves to submerge the wool in the scouring liquor In some cases, this ducker is in the form of a rotating metal drum equipped with metal blades In some machines, the false bottom is built up to a slight incline at the end of the bowl, which presents the wool directly up to the squeeze rollers In this case, an auxiliary rake or crab is provided, which takes the wool from the rake and passes it up to the roll, traversing the final 4 feet of the bowl This carrier generally oscillates at from two to four times the rake speed, the higher the ratio of oscillation, the thinner will be the sheet of wool fiber presented to the rollers and the faster the rollers will have to rotate to handle the feed. This type of feed is generally accredited with being most suitable for short, heavy-grease-content clothing wools Other machine types are provided with a single rake, extending from the feed end almost to the pressure roller, which is set lower than in the other types of bowls The wool is passed directly to the nip of the roller down a steep incline Some of the excess scouring liquor may escape through screened openings in the side or through slots in the perforated incline plate This type of feed presumably entails less agitation and entanglement However, while each of these features has its respective merits, the production and the type of wools being scoured are the pertinent factors in setting up a scouring train

In some European machines or "scouring leviathans," the wool is propelled through the bowls by means of individual rakes that are geared in unison and operate on a single pulley Each pair of rakes may run at the same or different speeds, depending upon the immersion time desired for each bowl The depth of the bowls to the false bottoms is considerably greater than in the American machines, consequently, the wool has greater freedom of motion therein This feature tends to give wools scoured in this type of machine a more stringy and felted appearance The wool is lifted from the liquor at the end of the bowl by a mechanism known as the Belgium lift This consists of three free-swinging forks, rotating on a common shaft, which dip into the liquor, grab and lift lumps of wool, and lay them on a moving lattice apron which presents them to the press roll

At the end of each scouring bowl, the wool is passed between two large press rolls. These wring the excess solution from the wool before it enters the next bowl The top roller is usually lapped with rubber and the bottom roller is of iron or brass The roll

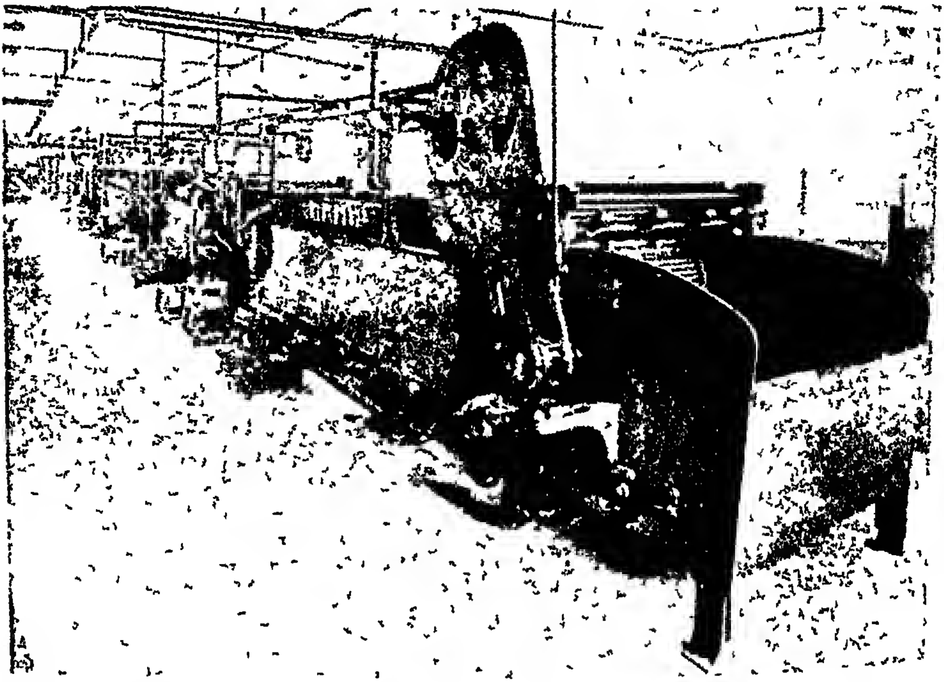


Fig 7 Modern five-bowl scouring train *Courtesy C G Sargent's Sons Corp*

pressure is maintained at between 3 and 12 tons and is created by compound levers and springs Slippage and stoppage is avoided by a system of gears motivated by a positive drive A tank is situated underneath the squeeze rolls to catch the surplus liquors squeezed from the wool This tank drains by gravity into the side or underneath settling tanks, or its contents are pumped directly back to the front end of the bowl to create a spray which assists in wetting and submerging the incoming wool The side or underneath settling tanks are furnished, generally, on the heavy scouring bowls. They have small capacity sections only, with tapered sumps that provide for partial sedimentation of the squeeze and overflow liquors prior to their use as a spray A wood or metal apron transports the wool from the squeeze roll to the next bowl

The most modern wool-scouring trains incorporate individual motor drives, with separate motors for squeeze roll, rakes, and pumps. This arrangement constitutes a decided improvement in efficiency, safety, and general appearance over the conventional overhead belt drive (Fig 7)

Besides the mechanical aspects, various factors, such as capacity, immersion time, speeds, and temperature, have a definite influence on scouring procedure. The capacities of the scouring bowls and the order in which they are set up in a train influences the function ascribed to each, the quantities of detergents necessary to produce a desired concentration and the frequency with which the liquors must be renewed. Experience has indicated that machine speed and immersion time have a pronounced effect upon the production and quality of scouring Recent trends have been away from long immersion times with a faster timing of the machines Properly controlled balance of detergents is much more conducive to good scouring than a longer immersion time Furthermore, the higher rate of swilling and the lesser degree of crowding created by faster speeds make possible higher production and lower chemical consumption

The production of a wool-scouring train is generally expressed as the amount of raw wool scoured per hour For a four-bowl train of 48 inch width, the production may vary from 1,000 to 3,000 pounds, depending on the shrinkage of the wool itself and the speed of the machine In terms of clean-wool production, the output may range from 500 to 900 pounds per hour Based on various shrinkages and the possible maximum production of 900 pounds of clean wool per hour, Table 6 gives the approximate amount of grease wool that can be fed to the scouring train

TABLE 6

AMOUNT OF GREASE WOOL FED TO THE SCOURING TRAIN

Per Cent Shrinkage	*Pounds of Raw Wool*
40	1,350
50	1,800
60	2,250
70	3,000

Temperature at the different phases of the scouring process plays an important part in the achievement of maximum efficiency A temperature above 100 degrees F is necessary to liquefy the wool grease since the melting point is about 100 degrees F Soda and soap can act efficiently only when the wool wax is in a liquid form In the event that the first bowl is used for preliminary steeping or de-suinting, temperatures between 90 and 110 degrees F have been found to be most satisfactory In the heavy scouring bowls, temperatures in excess of 130 degrees F should not be necessary, provided the proper balance of detergents is maintained In the rinse bowls, between 110 and 120 degrees F has been found to be the optimum condition for satisfactory rinsing

The Soap-Alkali Scouring Process

Chemical detergents The three primary chemical agents utilized in this type of scouring are water, alkali and soap Each of these performs a specific function in the chemistry of the scouring process and considerable quantities of each, subject to certain standards and specifications, must be available to the wool-scourer

Water and water-softening methods The availability of a large supply of water is a prime requisite The volume capacity of the average 48-inch scouring line may run between 5,000 and 10,000 gallons This volume of water must be available each time the water is changed, which may be once every eight hours or only once a week In addition, replenishment, rinsing and operational losses in the bowls necessitate an hourly consumption of between 500 and 2,000 gallons of fresh water This amount depends upon the type of wool scoured, the period of effectiveness of the scouring liquors, production requirements, the number and the capacity of the scouring bowls, the scouring procedure and whether or not grease recovery equipment is employed Water serves as the solution medium for soap and alkali as well as the dispersal medium for the impurities in the raw wool Water suitable for wool scouring must be available in abundant supply, of minimum hardness and free of sediment and suspended impurities Dissolved impurities, mainly magnesium and calcium carbonates and bicarbonates, whose presence in water is indicative of its degree of hardness, form insoluble soaps in the scouring process through interaction with the soaps used and formed therein These insoluble compounds adhere firmly to the fibers and are difficult to rinse out Their presence in the wool can cause considerable difficulties in dyeing, carding and combing. For this reason, whenever possible, treated or soft water is preferable in wool scouring Sediment and suspended matter may be eliminated by settling, often accelerated by chemical treatment Table 7 offers a quantitative measure of the varying degrees of hardness On this scale, water up to 75 parts per million hardness is permissible for wool-scouring

TABLE 7 RELATIVE HARDNESS RANGE FOR WATER
(In parts per million)

Less than 15	Very soft water
15 to 50	Soft water
50 to 100	Medium hard water
100 to 200	Hard water
Over 200	Very hard water

If water contains more than 86 parts per million of hardness, it is likely to cause difficulties The hardness can be removed by a process called *softening* The two methods of softening commonly used today are (1) the lime-soda method and (2) the zeolite method. The quantities of lime and soda required for the lime-soda process are determined by the hardness of the water The softening is carried out by means of an automatic apparatus There are two kinds, namely, intermittent and continuous softening In intermittent softening, the water is mixed with the necessary chemicals and the precipitated hardness allowed to settle The clear softened water is then drawn off In continuous softening, the precipitated matter is removed partly by gravity, but chiefly by means of a filter. This form of apparatus is more convenient, since it requires less room The essential parts of a water softener are a reagent tank that is at the same time a precipitating tank, the filter, and a soft-water tank The principle of the chemical reaction is that the soda and the lime react with the calcium and magnesium salts present in the water to form insoluble compounds which slowly precipitate. This precipitation can be facilitated by the presence of aluminum compounds The time required for the settling is about five hours in the intermittent type Through the lime-soda method the hardness of the water can be reduced to 1.5 grains per gallon only.

To a large extent, the zeolite method has replaced the lime-soda method This method depends upon the use of special minerals called *zeolites*, which are silicates of aluminum combined with calcium or sodium They occur in natural deposits as green sand, found largely in the southern part of New Jersey After washing and stabilizing the green sand, the zeolite is in the form of the sodium salt When hard water is brought into contact with the zeolite the sodium is replaced by calcium or magnesium, thus forming calcium and magnesium salts The sodium remains in the water as a bicarbonate of soda or sodium sulfate The reactions with calcium bicarbonate and sulfate are

Sodium zeolite + calcium bicarbonate = calcium zeolite + sodium bicarbonate
Sodium zeolite + calcium sulfate = calcium zeolite + sodium sulfate

To soften water by this means, the hard water is allowed to percolate slowly through a layer of this granular zeolite The water which issues from the zeolite filter is almost free from both calcium and magnesium—its hardness is 0 The reaction continues until all the sodium zeolite is changed into calcium or magnesium salts, indicated by hard water issuing from the filter If the calcium or

magnesium zeolite is now treated with a solution of salt, the sodium zeolite is regenerated:

Calcium zeolite + sodium chloride → sodium zeolite + calcium chloride

The soluble calcium chloride is carried away with the salt solution The residual salt and calcium chloride is washed away with soft water and the regenerated sodium compound can be used again The cycle can be continued indefinitely.

Alkali. The assistance of an alkali is required in the emulsification of the wool fat and dirt and to effect a partial saponification of the free fatty acid of the raw wool grease with the formation of natural soaps The cheapest and most effective alkali for this purpose has been found to be soda ash or sodium carbonate Its action is sufficiently mild so that, under judicious control, no damage to the wool fiber occurs, despite the susceptibility of the latter to stronger forms of caustic Soda ash is available from large chemical producers in the form of a finely divided white powder, which is 99 per cent sodium carbonate or 58 per cent sodium oxide It may be obtained in 100-pound bags or barrels or in bulk It is most easily handled in bags and, being in powdered form, is easily dissolved

In most scouring mills, the alkali is added to the scouring bowls either in a solid or a dissolved state The possibility of localized action and fiber damage is far more likely with solid addition, since some of the alkali may adhere to the fibers and be carried on through the rinse bowls and remain with the wool The solid ash is added either directly to the bowl proper or is placed in the squeeze roller sumps, wherefrom it is dissolved and carried off by the squeeze liquors Soda ash solution may be piped directly to the scouring bowls or added from side tanks by means of pails The most suitable means of addition is directly through pipe lines into the scouring bowls through which the flow of solution may be controlled by dispensers, fixed orifice plugs or patented flow meters calibrated to regulate flows from 10 to 100 gallons per hour. The lines are generally gravity fed from overhead storage tanks For the preparation of the stock soda ash solution, the most satisfactory system consists of a mixing tank of between 300 and 500 gallons capacity equipped with an agitator and cold and warm water inlets as well as a steam line, a large overhead storage tank of between 500 and 1,500 gallons capacity for storage, and a pump to transfer the stock solution from the mixing to the storage tank. Because soda ash is highly soluble, the strength of the stock solution may be relatively high, generally between 60 and 100 pounds per 100 gallons.

Soap. In addition to the natural soaps formed by saponification during the scouring process, considerable quantities of regular soaps are required. There are tremendous numbers of common soaps and synthetic detergents on the market at the present time Three factors should be considered in determining the suitability of these products for scouring: (1) chemical composition, (2) scouring efficiency, and (3) cost Generally speaking, the most suitable soap should incorporate a high degree of solubility and rinsibility, it should be neutral in respect to free caustic or free fatty acids, and it should be stable towards hydrolysis, oxidation and rancidity Experience has shown that low titer sodium flake soaps provide the greatest money value, considering scouring effectiveness per unit cost They also possess other desirable characteristics The titer of a soap refers to the melting point of the fatty acid from which the soap is made Experience has indicated that sodium soaps are superior to fig or potash soaps in the matter of money value, rinsibility and resistance to hydrolysis and oxidation Various synthetic detergents which have been applied in wool scouring have been found incapable of replacing soap or alkali or of improving the quality of scouring obtained by the use of alkali Furthermore, their cost in comparison to that of soap and alkali makes their use prohibitive Stock solutions and feeding equipment similar to those described for alkali dispensing may be applied to soap additions Generally, a concentration of between 40 and 60 pounds per 100 gallons is most suitable

Removal of the impurities from the wool fiber through the soap-alkali process involves an emulsification and partial saponification of the wool fat and suspension of the dirt particles, some of which are colloidal in size The solutions utilized for this purpose must possess strong surface-active and suspension properties Although soap solutions alone incorporate both of these characteristics, their capacity for reducing interfacial tension between grease and fiber is inferior to their colloidal-suspending power The addition of alkali accelerates their penetrating power and reduces interfacial tension considerably, although the dispersion and the suspension capacities are diminished The amount of saponification which occurs in the scouring process is a function of the free fatty acid content of the wool fat, and this varies with the type, grade, and origin of the wool Fine wools of high-grease content with a resulting high soap formation capacity make the scouring of such wools very economical, since only adequate additions of alkali are required to replenish that utilized in saponifying the fatty acids, whereas lower-grease-content wools, which are incapable of forming natural soaps

as rapidly as they are dissipated by operational losses, require periodic additions of regular soap as well as alkali

De-suinting method In general, it may be stated that two basic methods of detergent scouring are the most widely applied The principle difference lies in the purpose for which the first bowl is utilized In the first method, each bowl performs a specific purpose and is maintained for this purpose for its entire life The *first bowl*, in this case, is used as a steeping or de-suinting bowl with the temperature maintained between 90 and 110 degrees F At these temperatures, the suint salts are readily soluble and the maximum effectiveness may be derived from their colloidal-suspending properties to remove as many of the heavier dirt particles as possible It has been found that as high as 40 per cent of the total shrinkage may be removed in such warm-water steeping Above the temperatures indicated, the wool fat will melt and become slippery, causing difficulty at the squeeze rollers Below this temperature, the wool does not open sufficiently to permit penetration of the suint salts and to allow the dirt to disengage itself In certain wools, the percentage of suint concentration alone is as high as 10 to 15 per cent, it is evident that a considerable accumulation of salts and dirt will result therefrom within a short time, depending upon the wool production and the bowl capacity For this reason, periodic or continuous renewal is advisable in order to prevent the concentration from reaching the saturation point, at which time the efficiency of the bath would drop sharply

The *second and third bowls* perform the heavy scouring, with the greater percentage of impurities removed in the second The temperatures are maintained between 125 and 130 degrees F in each, and the bulk of the detergent additions are made therein Since most of the natural soaps will be formed in the second bowl, after the initial charge the additions to this bowl will be mostly alkali to replenish that used in saponification, whereas in the third bowl, which receives the wool in a much cleaner state, lower concentrations of alkali and larger additions of soap are required, the amount depending on the nature of the wool scoured

The *fourth and fifth bowls*, if present, serve as a rinse They swill out the soap, alkali, grease, and dirt carried over by the wool from the heavy scouring bowls If the previous bowls function properly, the wool will enter the rinse bowls at the desired residual grease content so that no detergents should be needed While some scourers are advocates of a soap rinse in the fourth bowl, experience has shown in mills operating a four-bowl train that excellent color and

texture can be obtained with just a warm-water rinse The most satisfactory rinse may be obtained at temperatures between 115 and 120 degrees F

Counter flow method In the second method, a counterflow of the liquors is employed in which the overflow liquors from the fourth or fifth bowl are run back continuously through the train to the first bowl Detergent additions are made to the first, second and third, first and second, or the second and third bowls, with the flowback carrying the soap and alkali back to the first bowl This method of scouring is far more difficult to control, since the volume of the flowback is not easily regulated and is continually affecting the bowl concentrations Furthermore, the buffering action of the suint salts in the first bowl prevents maximum formation of the natural soaps, so that the soap consumption is invariably higher and the alkali slightly lower when using this method. It may be concluded that, while the suint salts perform a useful function by themselves in the scouring operation, in the presence of soap and alkali they retard the scouring efficiency

Tables 8 and 9 show the quantities of detergents and other pertinent data for operating a four-bowl scouring train by each method on 64s Australian wool at a production of 1,500 pounds of grease wool per hour

TABLE 8 OPERATIONAL DATA FOR THE DE-SUINTING METHOD

Bowl	*1*	*2*	*3*	*4*
Length, ft	32	24	16	16
Capacity, gal	2,000	1,500	1,000	1,000
Initial charge, lbs				
Soda ash	—	75	10	—
Soap	—	10	7	—
Hourly addition, lb				
Soda ash	—	25	5	—
Soap	—	—	3	—
Immersion time, min	3	2½	1½	1½
Temperature °F	100	130	125	120

The data given in Tables 8 and 9 represents a starting point and not a universal procedure applicable to scouring all types of wools in all types of washers As mentioned previously, grade, origin and chemical characteristics are the principal factors governing procedure. For one thing, the medium- and long-wool types are less susceptible to the action of high alkaline concentrations than are the fine wools They are, likewise, heavier consumers of soap, since they do not possess the potential soap-forming capacity of the finer

TABLE 9 OPERATIONAL DATA FOR THE COUNTERFLOW METHOD

Bowl	*1*	*2*	*3*	*4*
Length, ft	32	24	16	16
Capacity, gal	2,000	1,500	1,000	1,000
Initial charge, lb				
Soda ash	80	30	10	—
Soap	10	5	5	—
Hourly addition, lb				
Soda ash	—	20	5	—
Soap	—	5	10	—

wools Proper scouring depends essentially on a correct balance between soap and alkali concentrations Experience has shown that, in scouring all types and grades of wool, concentrations of soda ash ranging from 4 to 8 pounds per 100 gallons are most satisfactory In the case of fine wools, soap concentrations will regulate themselves, whereas with medium and long wools, soap additions must be made according to the needs indicated by control

Control of scouring In view of the tremendous number of variables involved, the wool-scourer must avoid the pitfall of relying upon a fixed procedure in washing different wools. Some of the evidences of faulty balance of detergents are depicted in the following examples. (1) insufficient soap and alkali—poor color, appearance and high residual grease content, (2) excessive alkali—harsh feel, lack of luster and a high pH, (3) excessive soap—sticky or tacky feel, yellowish coloration and stringy appearance, (4) excessive soap and alkali—poor color, stringy appearance, lack of luster, high pH, and high residual grease content Each of these deficiencies is costly to the manufacturer in respect to the quality of his top or yarn, the amount of waste incurred in succeeding operations, and his operational efficiency. Control instruments have been developed by the American Chemical Paint Company which make possible rapid, on-the-spot determination of factors most pertinent to proper scouring, namely, the residual grease content of the scoured wool as well as the alkali, soap, grease, and dirt concentrations of the scouring liquors They are most helpful in setting up scouring procedures to obtain a quality product with minimum chemical consumption The instrument used to measure salt concentrations is a conductance meter, known as the Mackenzie potentiometer or *ridometer*

Measurement of alkaline concentrations during the scouring process is important in maintaining control of the individual baths Of the methods available, titration of the liquors with the use of standard acids and indicator solutions is the most elementary However, in-

accuracies in the estimation of end-points and the time-consuming nature of the procedure, especially in attempting to control more than one train, prevent wide reliance upon this control method Such titration, however, indicates the formation and steady building up of sodium bicarbonate as a by-product from the saponification of the fatty acids by the sodium carbonate, and it shows how the total alkalinity of the bath increases, although the soda ash concentration may vary only slightly These bicarbonates have a buffering action on the soda ash so that the possibility of damaging the wool fibers as the scouring progresses is nullified by the formation of these bicarbonates. It might be said, therefore, that these bicarbonates have a definite function in the scouring process On a single instrument by the turn of a switch, the Mackenzie potentiometer provides control of the individual scouring bowl by means of electrodes immersed in the liquor The readings are thus instantaneous and they indicate the total salt concentration of alkali in the scouring liquor, a close parallel to the total alkalinity found by titration pH control has proved unsuccessful due to the cumulative and everchanging nature of the scouring process and the fact that pH is a relative measure of alkalinity; thus a quantitative measure is required

With control scouring, it is possible to provide a scoured product of any desired residual grease Wool for use in woolen materials may be scoured anywhere from 1 to 3 per cent residual grease content, with the majority favoring about 1-5 per cent Wools for worsted consumption generally are maintained between 0 25 and 1 per cent The specifications in Table 10 represent the range of chemical conditions in a well-scoured wool

TABLE 10 SCOURED WOOL SPECIFICATIONS

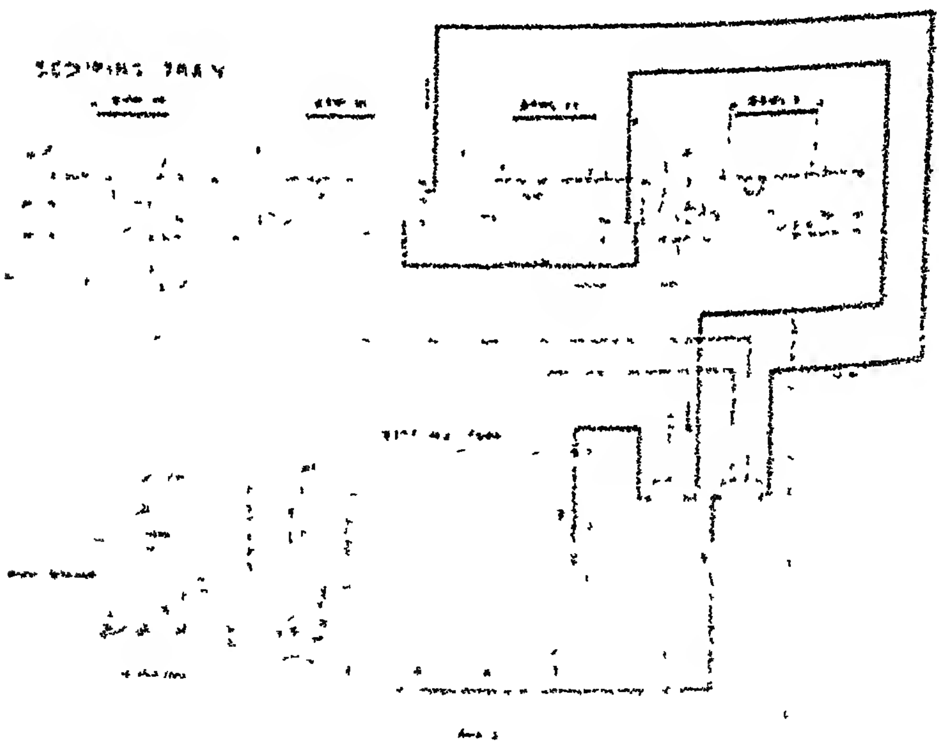
Residual grease content, %	0 50–0 75
Residual soap content, %	0 50–0 75
Ash content, %	1 0 –1 5
pH	9 0 –9 8

Wool Grease Recovery in the Soap-Alkali Method

Because of the objectionable nature of the effluent scouring liquids, pressure has been brought to bear upon the mill operators to subject these refuse liquors to some degree of purification prior to their being emptied into the stream Two types of purification treatment are generally employed · (1) acid cracking, (2) mechanical separation The former method is the older and has had wide use on the Conti-

rent. The latter method, which has gained wider acceptance in the United States through the American Chemical Paint Company[2] and the Sharples Corporation[3], was adapted from the French Duhamel[4] process. The advantages of this process include the recovery of a higher quality by-product, lower cost, higher production through a longer retention of scouring liquor and a minimum recovery [illegible]

The principles and procedures of scouring with grease recovery are identical with those of scouring outlined above. The de-suinting bowl is handled similarly, as are the heavy scouring and rinse bowls. In Fig. 5, a flow diagram of the handling of the liquors under the American Chemical Paint process is shown. In this method the grease [illegible]



[illegible]

scouring liquors of the heavy scouring bowls are subjected to high-speed centrifugal separation, which effects a partial removal of the grease and dirt The degreased liquors are then returned to the scouring bowls and reused Usually, these installations are made in such a manner as to be sufficiently flexible to permit all varieties of directional flow to cope with differences in machinery, types of wools scoured and other pertinent factors Systems have been set up utilizing first-, first- and second-, second- and second- and third-bowl recovery Of these, the latter two have been found to be most efficient whenever conditions are suitable

In recovering from the second and the third bowls, the squeeze liquors are taken from the squeeze roller sump on the second bowl and pumped through a heater in which the temperature is elevated to 190 degrees F They are then passed into a settling tank of about 3,000 gallons capacity, which is divided into three compartments, each having 60-degree pockets with valved outlets The liquor is skimmed from the surface of the last compartment and passed through a De Laval centrifuge, wherein a three-way separation is effected The grease ejection is collected, and a sludge discharge of from 100 to 250 gallons per hour is run into the sewer The degreased liquors are pumped through a heat exchanger, wherein the temperature is lowered to the proper scouring temperature, and returned to the third scouring bowl The overflow from the third scouring bowl is directed back to the second, thereby completing the circulation Naturally, similar charging and replenishment of the detergents is required in this type of scouring However, the longest possible retention of the liquors minimizes losses in production and allows greater economy in the chemicals required Under certain conditions, it is possible to keep the liquors in the heavy scouring bowls for as long as one week without change Of course, the liquors in the de-suinting and rinse bowls must be changed or renewed from time to time By this method, from 10 to 40 per cent of the total shrinkage of the wool may occur in the de-suinting bowl, from 50 to 70 per cent in the heavy scouring bowl and a small percentage in the rinse bowls

As mentioned previously, the detergent requirements for effective scouring are subject to the various physical and chemical characteristics of the wool The same applies to the grease yields from the various wools on this type of recovery process Fine, high-grease-content wools generally may be scoured with a minimum of chemicals and are most productive from a grease recovery standpoint Medium and long wools, which are lower in grease content, are incapable of re-

acting to form their own soaps and, consequently, require more chemicals and are quite unproductive in grease recovery. Lime-pulled wools are exceptionally expensive to scour because of their tendency to precipitate soaps and carbonates from the scouring liquors Accordingly, they are poor for grease recovery. Scouring chemical costs and recovery estimates are generally calculated in per cent, based on the quantity consumed or produced in relation to the amount of grease wool scoured In Table 11 are tabulated average production figures for chemical consumption and grease recovery for various grades over a wide range of mill experience. Soap figures are based on the quantity of anhydrous soap utilized, and grease recovery data are also expressed on a dry basis though the grease is recovered in the hydrous state.

TABLE 11 CHEMICAL REQUIREMENTS AND GREASE PRODUCTION FIGURES FOR VARIOUS WOOL GRADES
(in percent)

	Fleece			*Pulled*
Grade	*Fine* *62s–80s*	*Medium* *50s–60s*	*Long* *36s–48s*	*All* *44s–64s*
Soda ash used	2 5–4 0	3 0–5 0	3 0–5 0	3 0–6 0
Soap used	0 1– 0 5	0 3–0 6	0 3–0 8	0 3–1 0
Grease recovered	2 0–10 0	0 5–4 0	0 2–1 0	0 2–2.5

The Solvent Scouring Process

Wool has been scoured with soap and alkali since ancient times. Though this is still the principal method in use, there is another process radically different in principle but very effective that is being practiced to a considerable extent at the present time It is a well-known fact that oils and fats, though insoluble in water, are easily and completely dissolved by organic solvents such as benzene, petroleum naphtha, and carbon tetrachloride These solvents are easily evaporated at a comparatively low temperature and because of this property are known as volatile solvents In the laboratory such solvents are in daily use to extract fatty matter from raw and scoured wools Their use on a commercial scale for the purpose of freeing wool from its grease was first introduced in Europe around the year 1900

In the United States the process was introduced by the Arlington Mills at Lawrence, Mass, and by Erben & Harding at Philadelphia,

Pa Arlington has employed this process successfully since the early 1900s and handles at present more than one million pounds of grease wool weekly.

The principal operations in the solvent process are 1st, the removing of the fatty or greasy matter by means of a suitable solvent, 2nd, removing the excess solvent and 3d, washing away of the remaining impurities by means of a warm-water treatment The procedure at the Arlington Mills (Fig 9) is as follows The wool is packed into large vertical kiers of 2,500 pounds grease-wool capacity. The kier is then sealed and the air evacuated to a 25-inch vacuum The solvent, a high-test aviation gasoline, is then introduced The extraction of the wool grease is done in three steps, by passing thousands of gallons of naphtha liquors of three different degrees of purity through the wool The first extraction is done with dirty naphtha (previously used twice) which remains in contact with the wool until saturation, then this naphtha is emptied through a valve

Fig 9 Naphthalating plant showing battery of kiers used for degreasing
Courtesy Arlington Mills

in the bottom of the kier and replaced by a second filling of intermediate naphtha (previously used once). After a certain time interval the intermediate naphtha is emptied and replaced by clean new naphtha that reduces the grease content to approximately ½ per cent Whereas the naphtha of the second and third fillings is pumped into a storage tank, the dirty naphtha of the first extraction is redistilled

The naphtha left in the wool is removed by circulating a hot gas through the kier until all liquid naphtha is driven off Coming from the kier, the wet gas passes through a condenser, where the naphtha is removed, then to a heater to restore it to its former temperature and then is returned to the kier. To remove the last trace of gasoline the kier is vacuum-extracted again, and the evacuated air passed through a condenser and released into an airtight tank Fresh air is then allowed to enter the system and the kiers are ready to be opened After the opening of the kier, the wool is discharged through a manhole in the side of the kier onto a conveyor, which transports it to a special scouring machine In this machine, the wool is treated in its own suint with no other scouring agent added A series of long vats or bowls are so connected that water flows through them by gravity with an action like that of a natural stream The raw wool is moved wholly by the current, being floated like foam The natural suds, which form from the potash left in the wool, act on it without violence and require no forcible scouring Finally, the excess liquor is squeezed out and the wool is passed on to a dryer

The extraction is done in a closed system and scarcely any odor of naphtha is noted in the kier room Even when the kiers are opened they can be entered without discerning the odor of naphtha Every safeguard and safety measure is taken to prevent the highly inflammable solvent from coming in contact with explosive agents According to statements by officials of the Arlington Mills, no fire or explosion has occurred during the long operation of this plant The installation is housed in a specially designed building, separated from all other buildings by a high wall and connected with the wool storage and scouring departments by two covered passageways

The chief advantages of the solvent process are the superior working quality of the tops and the yarns produced, as well as the strength and softness of the finished goods It is said that the defects of the soap and soda system of scouring, such as alkali damage and partial felting, are eliminated The wool is in a more open state and thus can be carded with less fiber breakage There is no doubt

that from a physical and chemical standpoint the solvent process is superior to the soap and alkali process In practice, however, it is attended with great difficulties such as the necessity of handling inflammable solvents in large quantities and the high cost of installation and maintenance These drawbacks have kept the solvent process, in spite of its many advantages, from being more generally adopted in the United States

Continuous Wool Degreasing

Recent years have brought several new developments, indicating that the situation in scouring may change in the future. With the introduction of stainless steel the machine builders have found a

Fig 10 Continuous wool degreasing unit *Courtesy Smith, Drum & Company*

material which is able to resist the corrosion of noninflammable solvents such as trichlorethylene and carbon tetrachloride

The Derby continuous dry-cleaning process, introduced in 1939 in woolen and worsted finishing, has proved that this can be done

successfully This encouraged several machine manufacturers to begin development of a continuous wool degreasing unit using the solvent process Figure 10 illustrates a model machine, designed by Smith, Drum & Company, for the continuous degreasing of wool by treating the wool in mat form as shown emerging from the machine After processing, the solvent is recovered and reused The dirt which is removed during the processing is delivered from the machine as a dry dirt (that may have some fertilizer value) and the wool grease is also recovered The solvent processing section employs the countercurrent flow system and the amount of fresh solvent fed to the machine may be varied to control the amount of grease to be left in the wool

Frosted Wool

The frosted wool process was introduced as new and revolutionary in 1935, but it did not survive World War II The two mills that installed this process discontinued its use at the beginning of the war

The underlying principle of this process was subjecting wools to sufficiently low temperatures (30 to 50 degrees below zero Fahrenheit) to freeze their natural grease content thoroughly, and then opening and dusting them at this subzero temperature The freezing process congealed the natural grease in the fiber to a very brittle state, and the subsequent opening and dusting shattered it to a powder, quickly removing a considerable portion of it from the wool Substantial amounts of grass, burrs, seeds, chaff, shive, pitch, tar, paint, tags and earth impurities were also shaken out The wool so treated was delivered in a dry, open, and lofty state, but scouring was necessary to remove the grease and dirt remaining in the wool

WOOL DRYING

The wool should enter the dryer with a water content of not more than 50 per cent to prevent low drying production Extraction may be necessary in some mills to assure the proper water content of the wool The principle of the modern wool dryer is a flow of hot air, produced by steam pipes placed either in a separate compartment or in the dryer itself, and circulated by means of fans The tendency is toward a high velocity circulation at low temperatures rather than high temperatures with no provision for forced circula-

tion Various types of dryers are being used The two principal forms are. (1) single apron dryers of the direct-path type, (2) multiple apron dryers with three or more aprons

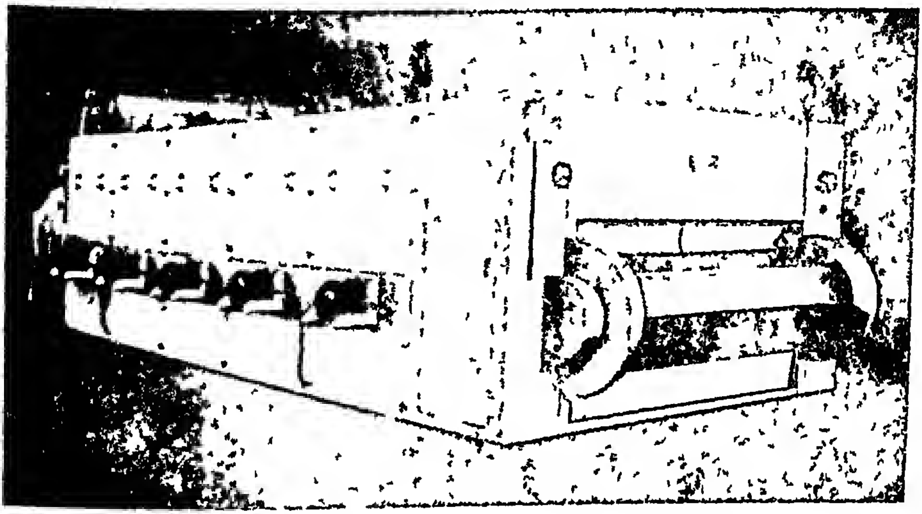


Fig 11 Single-apron dryer for loose wool
Courtesy James Hunter Machine Company

Single-apron dryer This type of dryer (Fig 11) works as follows the wet stock falls onto the wire aprons at the feed end of the dryer As it is carried up on the conveyor or through the dryer, the hottest air is applied at the feed end of the unit The stock passes from section to section at a predetermined speed (heating coils are graduated), giving up its moisture gradually The temperature of the air in each succeeding section is lowered in accordance with the moisture content of the wool The last section of the dryer at the delivery end serves as a cooling device, and the material is delivered from the dryer with a normal moisture content of about 12 percent

The air circulation in the dryer is as follows The fresh air is sucked into the dryer through an inlet located at the delivery section of the machine As it passes through the warm stock the air gets a preliminary heating as it cools the stock The air is then sucked into the first fan inlet, and discharged through the heating coils After passing through the heaters, the air continues down through the stock, so no upblast can lift the stock up and off the aprons Thus,

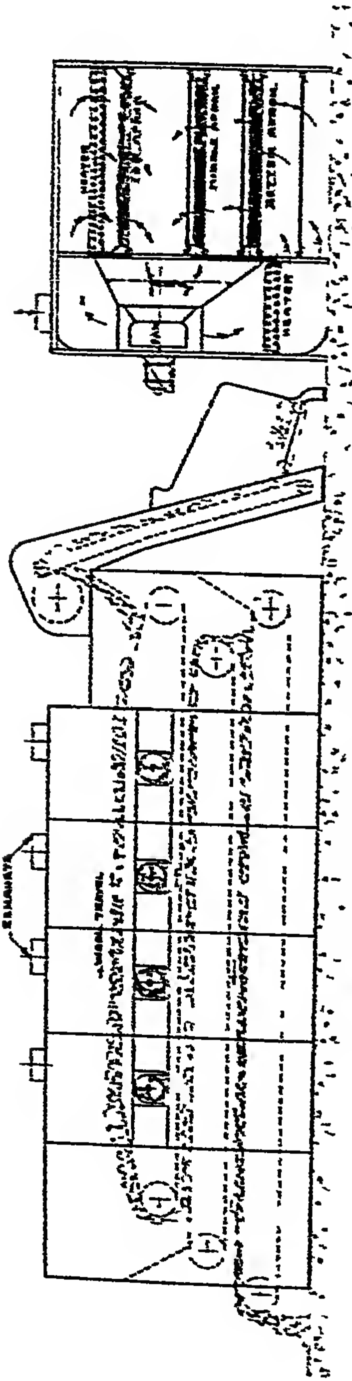


Fig. 12. Sectional view of three-apron wool dryer
Courtesy James Hunter Machine Company

the air current is split up, some of it returning to the first fan for recirculation, and the balance being sucked into the fan inlet of the next section This method is repeated as many times as there are sections in the dryer until the air, practically saturated, is exhausted by the fan in the feed section.

The size of the single-apron dryers varies from a machine 28 feet long and 10 feet wide with an hourly capacity of 600 to 800 pounds grease wool up to a dryer 43 feet long and 10 feet wide with 1,200 to 1,800 pounds per hour grease-wool capacity. The single-apron dryers today are considered the most efficient in drying capacity and by far the easiest to clean

Multiple-apron dryer This type of dryer (Fig. 12) is used to a considerable extent in woolen mills and is especially useful where the floor space is limited. To obtain the proper capacity the drying surface has to be built in height rather than in length as in the single-apron dryer. These dryers are generally made with three or five aprons, hence "multiple"-apron dryer. In this type of dryer, the material passes the length of the machine on the top apron, then drops to the second apron, where it again traverses the drying chamber. It then drops to a lower apron, returns the full length of the drying chamber, and emerges from the dryer. With this arrangement the stock is turned over twice on its way through the machine, permitting more uniform drying. Because of this feature the dryer is of special value for drying long-fiber stock or semicotted wools.

These dryers are made with cast-iron frames, steel panels and asbestos insulation, the housing is similar in construction to the single-apron dryer They are also made in varying widths and lengths to conform to mill requirements

BUR-PICKING AND CARBONIZING

All wools contain a larger or smaller amount of vegetable matter, burs, seeds, twigs, leaves, or straw picked up by the sheep in grazing This vegetable matter is generally referred to as burs and the fleeces which contain them in large amounts are referred as to *burry* wools or fleeces

The variety of vegetable matter present in wool is as wide as the variety of vegetation found on the sheep ranges of the world Probably the most recent and best source material on this subject is by Milthorpe[5] who lists over 50 species from over 40 genera However, the vast bulk of vegetable matter commonly found in wool is composed chiefly of a comparatively small group of plant burs and particles A photograph of the most common types of vegetable matter appears in Chapter 23 on page 945

The most common types as described by Wollner, Tanner, and Michelson[6] are the following

(1) Spiral bur, trefoil bur, or bur clover (genus *Medicago*), is the type occurring most frequently and the one most difficult to remove mechanically It may be present in scoured wool to the extent of 30 per cent The burs vary in size and weight The large burs are 5-7 mm in diameter and have an average weight of 14 mg The medium burs are 3 5-5 mm in diameter, average weight 10 mg The small burs are 2-3 5 mm in diameter, average weight 5 mg

(2) Shive, which is the term commonly applied to small plant fragments and slivers, is encountered very frequently It has been found to comprise as much as 6 per cent of some scoured wools Shives are very light, usually under 1 mg per particle, so that a very large number may constitute only a small percentage by weight

(3) Cockle bur or Bathurst bur, (genus *Xanthium*) is the next in order of frequency of occurrence While it may occur in very high

[5]Milthorpe, E J, *Vegetable Matter in New South Wales Wool Clip* The Central Wool Committee Testing House, Sydney

[6]Wollner, H J, Tanner, L and Michelson, I, *American Dyestuff Reporter*, 33, pp 375-8, August 28, 1944

percentages in some raw wools, it falls out comparatively readily in picking and scouring, and therefore rarely exceeds 5 per cent in scoured wools. The largest size, called the *Noogoora* bur, ranging up to 25 mm has a very thorny body firmly entangled in the wool, but is seldom encountered The medium size burs are 10-12 mm long, average weight 63 mgs. The small burs are 7-10 mm. long, average weight 41 mg.

(4) Sandbur, (genus *Cendrus*), occurs occasionally in some wools It has a few long, sharp, rigid spines, does not fall out of the wool easily, and rarely exceeds 4 per cent in scoured wools. These burs do not occur in clumps Those found in wools range from 7-11 mm in size, average weight 17 mg each Sand burs are very similar to the single fruits from the genus *Bassia* spp. such as galvanized bur, roly poly and others

(5) Barley grass (genus *Hordeum*) is occasionally found in small quantities, rarely over 1 per cent Measuring 8-12 mm, these burs average 5 mg. each

(6) Paraguayan bur, or sheep bur, (genus *Acanthospermum*), has been found in a few wools It is fairly smooth, with a few longitudinal corrugations, and falls out of the wool easily, so that scoured wools seldom contain as much as 2 per cent. The burs are 5-7 mm long, average weight 15 mg

If the burs are not removed from the wool after the scouring process they are broken up into innumerable small particles during succeeding operations, mainly in carding When present in large amounts, they cause considerable difficulty in all manufacturing processes They may damage the card clothing and combs Remaining in the roving they cause the yarn to spin unevenly, resulting in many breaks and a *twitty* yarn As part of the yarn, the burs will pass through all of the manufacturing processes and into the finished cloth They are known by various names such as specks, motes, and burs. Vegetable matter does not absorb wool dyes in the same proportion as the wool fibers, consequently, the burs are noticeable on the surface of piece-dyed cloth as specks of a lighter color or no color at all These must be picked out by hand to make the cloth salable

These conditions necessitate the removal of all vegetable matter from wool at the earliest possible stage of manufacturing This removal is done directly after scouring and drying, by two methods 1) by the mechanical method, and 2) by the chemical method The choice of method depends entirely on the purpose for which the material is to be used later on If it is intended that the material is to

passing the wool to the second bur cylinder which runs at a speed of approximately 700 r p m and thus strips the wool from the first cylinder This stripping action reverses the position of the stock in its relation to the cylinder, so that the fibers which were innermost on the first cylinder are now on the surface. The second guard, which works in connection with this cylinder at a speed of over 1,800 r p m, wipes the burs from the cylinder and throws them out on top of the picker into a bur pan from which they are removed by a leather clearer, traveling transversely on the housing The wool is finally removed from the bur cylinders by a brush which consists of wooden cross-bars set with stiff bristles and ten lags, rotating at a speed of more than 1,800 r p m Finally, the wool is conveyed by a suitable pipe to the storage room This machine is especially suitable for short wools For picking and burring long-staple wools, there has been developed the duplex machine, which is somewhat similar to the multiplex machine, but, unlike the latter, both of its cylinders simultaneously strip stock from the main cylinder

Most mills are equipped with three sets of bur cylinders, a fine set for fine wools, a medium set for medium wools, and a coarse set for coarse wools

The necessity for these three sets is that, if a cylinder with fine teeth is used for coarse stock, the wool will not penetrate the spaces between the steel rings or teeth Also, some of the fiber will be broken when a large amount of wool is knocked into the bur box by the guards On the other hand, if cylinders covered with coarse teeth are used for fine stock, much of the wool will be pulled from it and cast out.

Peralta process A second, more recently developed method of removing foreign vegetable material from the wool is by means of the Peralta roller mechanism, which may be attached to the cards This process is discussed in full in the chapter on carding (Chapter 12) The object of these rollers is to crush any hard, thready material (bur or shive) present in the card sliver

Carbonizing

The chemical removal of vegetable matter is known as *carbonizing* The principle of this operation is to destroy the vegetable matter by means of acids such as sulfuric or hydrochloric, or by salts such as aluminum chloride, which produce acids when heated to higher temperatures The acid reduces the vegetable matter to carbon which is removed by mechanical action during dusting and neutralizing The

chemical method is far superior to burring because every trace of vegetable matter can be removed. Two procedures are followed the sulfuric acid process and the aluminum chloride process In the sulfuric acid process, the wool is treated in four steps

1 The steeping of the wool in acid
2 The baking or burning process
3 The dusting of the wool
4 The neutralizing of the wool

The first operation is the steeping or immersion of the scoured wool either wet or after drying in a 3 to 5 degree Bé, or a 4 to 6 per cent solution of sulfuric acid at normal room temperature The length of immersion time depends on the equipment available, the character of the wool and the amount of burs present When soaking is completed, the excess acid is removed by hydroextraction, vacuum-extracting or squeezing through rollers, leaving a moisture content of approximately 40 per cent, which is equal to 5 to 6 per cent of actual acid

After the extraction, the wool enters a specially built dryer or baking oven, where the wool is subjected to gradually increased temperatures in the succeeding sections, finally reaching a temperature of 200 to 220 degrees F at which the baking takes place In the previous sections all the water has evaporated, leaving concentrated sulfuric acid Under the influence of the concentrated acid the vegetable materials become charred as a result of the loss of the chemically combined water

This charred substance, which is chiefly carbon, is removed by a mechanical crushing known as dusting In the dusting procedure the wool passes between a series of heavy crush rollers that pulverize the carbonized matter, which is then shaken or beaten out of the wool

In order to remove the excess acid and to make the wool suitable for subsequent operations, neutralizing is necessary The principle of neutralizing is based on the salt-forming properties of the acid when brought in contact with an alkali. The most commonly used alkali is soda ash or sodium carbonate For this purpose the wool is rinsed first in cold water and, after at least 50 per cent of the acid is removed, it is treated in a weak soda bath for complete neutralization When necessary, the excess alkali is removed by rinsing

Neutralizing is carried out in the wool-scouring train Four bowls are usually employed The first bowl is lead-lined to prevent corrosion by the acid It is built as a rinser with a continuous flow of fresh water The second and third bowls are neutralizers, containing a weak soda

solution at a concentration of one-tenth of 1 per cent. The fourth bowl is kept slightly alkaline and soap may be added to improve the color of the stock Soap can be added in the third if the wool is very dirty Commission carbonizers add a blueing to the last bowl to whiten the wool After leaving the last bowl, the wool passes through squeeze rollers into a regular raw-stock dryer.

The aluminum chloride process is carried out in the same manner except that neutralizing can be dispensed with Aluminum chloride is a milder agent than sulfuric acid, and therefore the danger of injuring the stock is less The immersion is done in an aluminum chloride bath of 6 to 8 degrees Bé The wool stock should be absolutely free of soda before it enters the bath, because the soda will form a precipitate with the aluminum chloride, reducing the strength of the bath and thickening it to such an extent that carbonization becomes ineffective The best way to prevent this is to run the wool through a weak formic acid bath before immersion When this is done the aluminum chloride bath can be run for months without changing The aluminum chloride hydrolyzes to form aluminum oxychloride and hydrochloric acid Much higher baking temperatures (of approximately 250 degrees F), are required to release the hydrochloric acid The wool then goes to the carbonizing duster as before, except that in place of neutralizing, a thorough rinsing in warm or cold water is sufficient

The magnesium chloride process is also possible but has not been used commercially to any extent in the United States The sulfuric acid process is by far the cheapest Carbonizing is not confined to raw wool alone Actually a much greater amount of wool is carbonized in the form of piece goods as a part of the finishing process. (See Chapter 19, Wet-finishing Operations)

Various types of machines are used for carbonizing The older method is to steep approximately 200 pounds of wool in large tanks for forty minutes or an hour This method is now being replaced by continuous movement of the wool through bowls, similar to those used in scouring, and which are directly connected with a continuous dryer or baking oven In both methods, before the wool enters the baking oven, the excess acid has to be removed by hydroextracting or squeezing

The baking ovens are built on the same principle as an ordinary raw-stock dryer, but certain points have to be kept in mind At least two separate sections have to be provided where the temperatures can be kept at a definite level To ensure satisfactory carbonizing it is necessary that all water be evaporated before the wool enters the actual baking chambers Two-section carbonizing dryers give satis-

factory results for this purpose In the first section the temperature is held at 160 to 165 degrees F. and in the second section the wool is subjected to a temperature of 200 to 230 degrees F A squeeze roller on the end of the oven is attached with the object of pulverizing the carbonized vegetable matter, in order to facilitate dusting

The carbonizing duster is built like a willow or opener, except that the material must go through a series of heavy-fluted crush rollers before entering the cone duster The object is to reduce the carbonized burs to powder before the stock is subjected to the action of the rotating cylinder

Chapter 10

BLENDING AND WOOLEN CARDING

FOR the manufacture of wool yarns it is necessary to assemble the various virgin wools, now properly scoured and dried, as well as other raw materials such as noils, reused and reprocessed wools, not to mention rayon staple fibers and cotton and silk noils In other words, the many different types of raw materials must be obtained and properly prepared for the subsequent woolen carding and spinning operations Such operations may consist of bur picking for burry wools, opening for tacky wools or materials, dusting of dirty or dusty stock, oiling, mixing or blending, garnetting for thread waste, etc These operations are necessary, they are performed at the discretion of the superintendent of the mill and depend on the nature and condition of the stock as it was obtained in the market. The number of processes to which any given raw material is subjected is guided by the labor required, the cost of the process, the effect of the process on the final quality of the woolen yarn, and the purpose for which the latter is intended

BLENDING OR MIXING

The object of blending or mixing is the amalgamating of different colors or qualities of wool fibers, reused yarns, and reprocessed yarns of wool and cotton, wool and rayon staple, or any other desirable combination. The purpose may be to create a mixture of colors such as heathers, grays, or special effects but more commonly it is to reduce the cost of the ultimate yarn and cloth The matter of what and how to mix stocks is a technique that requires much practical experience as well as a working knowledge of all types of available raw materials and their relative cost per pound Hence, a wide leeway for novel effects exists in woolen yarn manufacture

It may appear that the mixing of all kinds of stock is a comparatively simple matter, but when it is considered that such stocks may differ widely in their physical structure and properties, it becomes exceedingly difficult to choose stocks or such proportions of different raw materials, which when blended or mixed, will produce a satisfactory yarn or cloth Skillful mixing may make money for a mill, because off-color lots, imperfect stock, or odd waste lots, which would otherwise be useless or a complete loss to the mill, can be

However, great caution is necessary to prevent impractical mixes that will result in poor carding and uneven or weak spinning yarn For instance, when a yarn of poorly mixed materials is examined under a microscope, a group of fibers is revealed in one mass or a part of the yarn and another mass in another part of the yarn The ideal mix is one in which the individual fibers of its component parts are so thoroughly blended that they cannot be distinguished easily and are a perfect amalgamation or blend of them all

To achieve a well-blended yarn, materials of similar nature and characteristics must be chosen which will have a tendency to mix readily and thoroughly The component stocks must have similar fiber lengths and diameters as well as about the same spinning qualities They must result in a yarn of sufficient evenness and strength to withstand ordinary weaving and knitting processes as well as to dye uniformly, when required

In preparing such mixes, each component lot must be well cleaned, opened, and freed of impurities before it enters the mix The most common practice in woolen mixing in the United States is to spread the materials on the cement floor of a separate room in layers of the various grades The different colors or component stocks are carefully weighed out and the grade or type of stock present in the greatest amount is first spread evenly over the entire floor to a few inches in thickness The next grade, occurring in the second largest quantity in the mix, is now spread evenly on top of this layer and so on, alternating the layers according to the quantities required in the mix until all component grades are used up and the whole mixture completed as planned

Some materials are more difficult to blend than others, also, some colors show up more easily than others in the carded blend, even if the stock is the same In order to make a good mix with shoddy, for instance, short fine wools are generally used, because the shoddy fibers are short and frequently of mixed colors The longer the shoddy the more valuable it is and it acts as a fine filler to make woolen yarns more bulky

The addition of cotton to wool in the manufacture of union or angola goods is a common practice Care must be taken that cotton is thoroughly opened in an opener or bur picker before using it in any mix Cotton has a different fiber length and requires different manipulation The wool must be oiled separately and thoroughly picked before it is mixed with the cotton, to which oil should not be applied The stock is laid out in successive layers of cotton and wool and then run through a mixing picker a sufficient number of times to

ensure perfect blending For exceptionally fine yarn or work the cotton and wool are sometimes subjected to a garnetting or rough carding before making the mix The mixture, in either event, is run through the mixing picker several times to blend the cotton and wool in the right proportions American cottons are well suited for mixing with wools of various types. Where the wool is coarse, Peruvian or Brazilian cottons are preferred For very fine wools a long staple cotton such as Sea Island should be used.

If colored cotton is required, it is found that black combines well with all colors with the exception of those lacking in brightness In gray blends, occasionally, a rusty hue is encountered which can be overcome by dyeing the black on the bluish side In making white mixes of wool and cotton, the latter is usually blued a little to take away the chalky-white appearance of the cotton

In 50-50 blends of black and white, it is good policy to dye some of the wool and the cotton black separately and mix them together thoroughly. Colors on both cotton and wool must be reasonably fast to avoid crocking in the goods as well as bleeding of the dark colors into the white or light colors Mixes of wool and cotton, especially when mineral oils are used, should not be mixed and then allowed to stand around They should be immediately sent into the card to prevent too much absorption of the oil by the cotton Of course, it is to be borne in mind that such mixtures, if not properly balanced, will affect the spinning of the yarns and cause a difference in cloth shrinkage. Practically the same precautions apply to rayon staple fiber as to cotton.

When it is necessary to mix silk and wool, some difficulty is encountered at times with the silk, which is used in the form of noils or waste. Generally, the silk noils or waste are dyed to shade and then thoroughly opened on a garnet or waste card. The mix is then made by oiling the wool separately, but no oil is applied to the silk If a large percentage of silk is used and there is difficulty with the silk, it may be necessary to dampen the silk in a humidified room or lay wet bags on it Water should never be applied directly as that would cause lumping. Of course, all colors should be fast to bleeding and crocking The mixes are run through the picker a number of times to ensure uniformity of mix and satisfactory carding Great care is necessary to prevent static electricity as well as gumming of the ingredients on the cards

In the mixing of dissimilar fiber types such as wool and cotton or wool and rayon staple, quite frequently such mixes are not consistently uniform or they do not remain so when picked up

and fed to the mixing picker. To eliminate such indiscriminate feeding and guess work, the Benoit system of mixing was invented (Patents 1,929,344 and 2,141,782) In this system the stock is handled in batches or masses of a convenient size for one operator Each batch or mass is built by placing layers of stock horizontally in the desired proportions. Each successive lot is a rectangle of substantially the same size, composed of parallel layers of stock Uneven lots resulting from guess-work and carelessness are thereby eliminated After it is laid, each of these lots is advanced endwise to devices that remove the stock by continuously combing or hooking it off, taking an equal amount in thickness from each layer each time so that the stock that is carried along is continuously uniform The stock is then delivered to a mixing picker.

OILING OF THE STOCK

Wool stock or mixtures of wool with other textile fibers must be lubricated to minimize breakage of the wool fibers in opening processes such as rag picking and carding, as well as to reduce fly, waste, and static electricity in carding Oil on the wool is also needed to increase the cohesion of the fibers in a loose sliver, thus facilitating drafting, condensing, and spinning The extent of breakage of wool fibers during carding, while ultimately determined by the speed and the settings of the card, is influenced by the degree of entanglement of the wool that occurs during scouring and by the temperature and regain of the wool during carding

In spinning, the lubricant enables the wool fibers to slide over one another more easily during the drawing and twisting, resulting in a more even yarn However, there has to be a small amount of drag to prevent quick release, which would result in breakage of the roving or ends down in spinning It is good practice to apply the lubricants before or during the mixing of the stocks The kind of lubricant, the amount, and the method of application are of considerable importance if later difficulties in carding and spinning are to be averted

The essential requirements for a wool lubricant that fulfills these purposes are:

1 Good lubricating value in carding and spinning
2 Should not cause or support spontaneous combustion
3 Should not discolor the wool
4 Should not in any way impair the strength of the fiber
5 Must not cause rusting or corrosion of card clothing

6 Should not reduce the life span of the leather aprons or condenser tapes

7 Should form a stable and uniform emulsion with soft and moderately hard water in a temperature range of 70 to 100 degrees F

8 Must remain stable in storage under various conditions of temperature

9 After serving the above purposes, the wool oil should be easily removed by scouring with economical amounts of any good soap solution

An experienced mill man will, over a certain length of time, be able to detect the deficiency in any one of these basic requirements, but very often much damage is done before it is realized that an oil is unsuitable

The oil must lubricate the fiber Some oils may be excellent lubricants at a temperature of 70 degrees F and higher, but on lowering this temperature to 35 to 40 degrees F, as is often the case during the winter months, they become less fluid This lack of fluidity impairs their lubricating quality, resulting in gumming of the card clothing, clotting of the fibers, increased fiber breakage, and poorly carded webs or slivers Many oils are excellent stock lubricants and unaffected by temperature changes but may have a drying effect on the rub aprons and dividing leathers The result is that the leather surface gets rough and an inferior roving is produced

A good lubricant should not cause spontaneous combustion Unsaturated oils such as cotton-seed oil and soybean oil, which, because of their ready oxidation, can easily cause spontaneous combustion are unsuitable for lubricating wools Even nondrying oils such as peanut oil and red oil have been known at times to cause spontaneous combustion Especially in heavily lubricated stocks such as card wastes rapid oxidation of the oil can take place and the heat thus generated has caused many fires Card wastes are the most dangerous wool stock in this respect because they contain up to 30 per cent or more of oil In addition, they contain iron particles in the form of short card wires and fine dust from the grinding of the card clothing This iron will act as a catalyst, leading to the rapid oxidation of the oil The danger is further increased with dyed material as oxidation is catalyzed by certain dyes, olive drab wastes have proven especially hazardous in this respect

The water content of the waste in the presence of air and light also exercises a catalytic action on the oils, and the fatty acids that are produced promote the oxidation A good antioxidant for vegetable and animal oils is lecithin, a phosphatide extracted from corn oil,

which is effective in the amount of 0 20 per cent, based on the weight of the oil

The discoloration of the wool is caused mainly by the use of low-grade fatty oils or cheap conventionally refined mineral oils Solvent refined or properly treated mineral oils will not discolor white wools containing 6-8 per cent oil after exposure in the Fadeometer for 20 or more hours This color cannot be removed by scouring

A good scourability is very important in any wool lubricant When it is not uniformly removed from the fabric the lubricant can cause uneven dyeing, and often render the fabrics unfit to be marketed as first-class merchandise In knitting yarns, which are often not even washed, it is very important that the lubricant has no objectionable odor A good stock lubricant must not contain any strong alkali that will impair the strength of the fibers It should also be free from ingredients that necessitate the use of strong scouring agents for their removal because the fibers will be weakened

The presence of free mineral acids or other corrosive constituents will attack the polished steel parts of the machinery, they will dull and corrode the pins of the card clothing as well as the pins of fallers and combs It is very bad practice to oil improperly neutralized, carbonized stock as the acid in the wool will attack the card clothing wires no matter what oil is used

Types of Wool-Lubricating Oils

The range of oils suitable for wool lubrication has increased considerably since 1920 due to the extensive research which has been done in this field This research was instigated because of the shortage of animal and vegetable oils, especially olive oil, which had been the standard lubricant in the worsted industry, and the high prices which resulted from the scarcity of the oils This shortage of oils became even more acute during World War II and the early postwar period

The Technical Committee of the National Association of Wool Manufacturers has estimated that in normal years the worsted branch of the industry alone consumed approximately 800,000 gallons of wool lubricants The consumption of lubricants in the woolen branch would be about 4,000,000 gallons, or approximately five times as much In 1942, the War Production Board reported 25,000 barrels of oil used by Bradford spinners, 3,500 barrels by French spinners and 139,000 barrels by woolen spinners Calculating one barrel as 50 gallons, the total amount of oil used in the woolen and worsted industry during the peak year of production amounted to 8,375,000 gallons

Table 1 gives the average amounts of oils used in the various systems of spinning as reported by the committee.

TABLE 1 AMOUNTS OF OIL USED FOR FIBER LUBRICATION

Worsted	Bradford carding and combing	3 75% weight of top
Worsted	Bradford drawing	0.25% weight of top
Worsted	French combing	0 75% weight of top
Worsted	French drawing	0.25% weight of top
Woolen	Picking and carding	11 0 % weight of clean wool

Note. The figure of 11 per cent for woolen picking and carding seems high, but it must be realized that reprocessing of wool requires high amounts of oil

In recent years the Technical Committee has, in conjunction with Arthur D Little, Inc ,[1] investigated thoroughly the possible substitutes for olive oil as a lubricant in wool combing The most promising lubricants, as reported by the Committee in 1942, in the approximate order of preference are

1. Lard oil and mineral oil. Proportion 50-50.
2. Pure refined peanut oil and mineral oil. Proportion 50-50
3. Sulfonated red oil plus mineral oil. Proportion 33⅓-66⅔.
4. Mineral oil sulfonate plus mineral oil. Proportion 20-80
5. Neat's-foot oil and mineral oil Proportion 50-50
6. Cocoanut oil and mineral oil. Proportion 50-50.
7. Hydrogenated sulfonated soybean oil and mineral oil Proportion 20-80.

The results of the research done by this committee show that olive oil can be replaced not only by various vegetable and animal oils, but also that a partial replacement of these oils by high-grade mineral oils is possible.

When mineral oils were first introduced as lubricants in lower-grade woolens, such as reworked wool stock, the lowest type of the petroleum fractions was used The disadvantages of mineral oil when applied to higher-grade stock were soon recognized: high discoloration and low scourability For years the introduction of mineral oils for better-grade stock was discredited In late years, however, the mineral oil producer has brought on the market highly purified oils, such as solvent-refined or white mineral oils. They have gained more favor and are extensively used today, in high- as well as low-grade stocks, especially in woolen spinning.

[1] *Bulletin* of the National Association of Wool Manufacturers Vol LXXI, pp 503 618 (1941)

Based on general experience with various formulae the opinion still prevails that the use of a combing oil containing more than 50 per cent mineral oil is not advisable since the mineral oil requires more soap for removal than any vegetable or animal oil The ideal wool lubricant from the viewpoint of scourability would be a water soluble oil Such oils, the mineral oil sulfonates, have recently been introduced by various manufacturers and are already finding considerable use in the industry

The present specifications for the worsted lubricants (refined mineral oil and lard or grease oil) are given in Tables 2 and 3

TABLE 2 REFINED MINERAL OIL SPECIFICATIONS

Flash point, °F	400 min
Viscosity at 100° F	190-210 Saybolt seconds
Pour, °F	30 max
Color N P A	2½ max.
Neutralization number	0 10 max
Saponification number	0 2 max.
Evaporation loss	0 25 max
Light stability	There shall be no more than a barely perceptible change in color when worsted cloth containing 10 per cent of the mineral oil is exposed for twenty hours in the Fade-Ometer

TABLE 3 LARD OIL, OR GREASE OIL, SPECIFICATIONS

Grade	Extra winter strained
Free fatty acid, per cent	2-4
Cold test, °F	40-45
Specific gravity	912- 919
Saponification number	193-198
Iodine number	65-76
Unsaponifiable matter, per cent	1 max
Color N P A	2 max.

The oils formerly were applied without admixture of water, a method which has the disadvantage that the oil cannot be evenly distributed and therefore will not penetrate the stock uniformly unless stored for long periods of time Today, such oils are applied in emulsion form, which means they are mixed with water and an emulsifier resulting in a milky white emulsion The application of the oil in emulsion form gives the spinner a chance to add at the same time a certain amount of moisture to overdry wools The concentration of the emulsions varies with the type of wool or mixture of stock and according to the spinning method In woolen spinning, a strength suitable for wool and noil blends is a 40 per cent emulsion (2 parts oil

and 3 parts water). For luster wools and hair mixtures such as mohair blends, 25 per cent emulsions are suitable The amount of these emulsions that should be added to the stock is based on the amount of pure oil needed per hundred pounds of stock. For example, to apply 5 per cent of oil (5 pounds) to 100 pounds of wool, 12½ pounds of the 40 per cent emulsions are required and 25 pounds of a 40 per cent emulsion are needed if the oil content desired is 10 per cent In mill practice the oiler is instructed as to the total amount of emulsion to apply to any given quantity of stock For example, his instructions on a 50-50 noil wool blend of 1,000 pounds will call for a 25 per cent emulsion or 250 pounds for the total amount of wool.

For worsted spinning two types of emulsions are normally made One for the carding, gilling and combing process has a strength of from 20 to 25 per cent The emulsion is normally applied to the scoured stock as it comes out of the delivery end of the dryer Three to 4 per cent, which is equal to approximately 1 per cent oil, is used A second emulsion of 12 to 16 per cent strength is used to advantage in the drawing or preparing of the roving The amount added to the sliver may vary from less than 1 per cent up to 5 per cent or more, depending on the blend and the size of the roving (French System)

The British Wool Industries Association has in recent years conducted a very thorough and complete series of tests on the efficiency of various percentages of wool oil and the performance characteristics of wool oiled with straight oils and with emulsions For most grades of stock it was shown by their experiments that an oil application of from 6 to 8 per cent produced the greatest efficiency with respect to fiber breakage and cost of oil Experiments with heavier wool oil applications ranging up to 20 per cent based on the weight of stock indicated that more than 9 per cent oil did not give proportionately better results

A similar test was made to determine the efficiency of wool oil applied straight and in emulsion form, using the same percentage of actual oil in each case The results proved that the same amount of oil applied as an emulsion gave 30 per cent better performance than the same amount of oil applied straight, provided the stock was stored less than three weeks It is now generally agreed that emulsion oiling is the best method of applying wool oils to stock that is to be carded and spun into woolen yarns without prolonged storage

Making the Emulsion

The ingredients necessary to make the emulsion are oil, water, a

fatty acid (which may be already part of the oil), and an emulsifier. The most common emulsifiers are alkalies such as soda, borax, ammonia, triethanolamine, and stearamide The emulsifiers form soap with the fatty acid present and the soap produced divides the oil into fine particles, forming the emulsion It is very important that the emulsion produced be very stable, i. e, that it does not separate quickly The stability of an emulsion is determined by the size of the oil globules, which must be 4 microns or 1/6310 of an inch or more in diameter Any colloidal dispersion or emulsion containing globules below 4 microns will show Brownian movement. To be called stable, an emulsion should remain at least forty-eight hours without separating.

In large mills it is customary to buy the oil and emulsifying agent separately and produce the emulsion with the help of a stirring device The following are the main methods by which the various ingredients may be combined and a proper emulsion formed:

1. The soap method, consisting of stirring the oil and water alternately into the soapy mixture of fatty acid and alkali
2 The water method, consisting of stirring the oil into a water soap solution
3 The soluble oil method, consisting of forming a clear solution of the soap in oil that emulsifies continuously when added to water
4 The stearamide method, consisting of stirring the oil at intervals into the stearamide paste and adding the necessary water

Soap method The following formula illustrates the making of a lard oil emulsion by the soap method:

Lard oil	40 pounds	Oleic acid	5 pounds
Borax ..	1 pound	Water ..	54 pounds

Working at ordinary temperatures add the dissolved borax, oleic acid, and 15 pounds of lard oil to the agitator. As soon as these three ingredients have been added (but not before) stir vigorously until the mixture is fairly homogeneous Then, add slowly with constant stirring 20 pounds of water, obtaining a thick, smooth emulsion Continuing at the same stirring rate, first add the remainder of the oil in small portions and finally the remaining water in a similar manner Emulsification is complete when the oil and water are evenly distributed This emulsion is white, creamy, and stable

Soluble oil method This method is particularly applicable to mineral oils The following are some of the formulas used

1 ALL MINERAL OIL

White paraffin oil	85 pounds	Oleic acid	10.0-12.0 pounds
Triethanolamine ..	4.2-4.5 pounds		

Because petroleum products vary greatly and because formulation by this method requires great exactness, it is always necessary to derive the optimum formula for the specific oil to be emulsified The method developed by Carbide and Carbon Chemicals Corporation[2] is to 85 grams of the white paraffin oil are added 8 grams of oleic acid with constant stirring until the solution becomes clear. Then 4 grams of triethanolamine are added with stirring. If the container is held to the light, the mixture will usually appear cloudy or show minute suspended droplets Oleic acid is then added drop by drop, with thorough stirring after each addition until the mixture becomes clear. The mixture should now emulsify in water, but the addition of a few more drops of oleic acid may produce a slightly superior soluble oil, that is, one that will remain clear on long standing and that will produce a stable emulsion The amounts of oleic acid are totaled and the formula can be converted to the basis of 100 pounds for large batch production

If the emulsion obtained from the formulated "soluble" oil does not have the necessary stability, the amine content of the oil can be increased slightly, and the additions of oleic acid drop by drop repeated When less stability is required of the emulsion, the proportions of amine and oleic acid can be reduced simply by adding more mineral oil to the "soluble oil" until an emulsion of the desired stability is obtained

The preparation of the actual emulsion is as follows

1 The oleic acid is weighed out as determined above and 10 pounds of mineral oil added with stirring until a uniform solution is obtained.

2 The exact amount of amine as determined above is added and the solution stirred until it is clear The solution becomes warm due to the reaction of the oleic acid and the amine.

3 This mixture, which is the "soluble" oil base, can be diluted immediately by stirring in the rest of the mineral oil, or it can be stored and diluted as desired Both the "soluble" oil base and the resulting "soluble" oil are stable indefinitely when made in the proper proportions

4 The "soluble" oil emulsifies spontaneously when poured into water However, the best method of emulsifying is accomplished by stirring the "soluble" oil with an equal volume of water until a creamy mass is obtained, and then diluting further with water as desired

2 LARD OIL-MINERAL OIL

Lard oil	37 pounds	Mineral oil (refined)...	50 pounds
Triethanolamine . .	4 pounds	Oleic acid	9 pounds
	Water		

[2] *Emulsions*, Seventh Edition, Carbide and Carbon Chemicals Corporation, pp 31 32

The procedure for mixing this formula is as follows To a container equipped with a simple stirring device 9 pounds of the mineral oil together with all of the oleic acid are added Stirring for a few minutes produces a homogeneous solution to which should be added the exact quantity of triethanolamine, which is mixed into the liquid until a clear solution results To this solution the rest of the mineral oil, together with the lard oil, is added and stirred sufficiently long to obtain a uniform solution

The soluble oil so prepared will emulsify spontaneously when added slowly to water and will form a stable white emulsion Dilution is best made by first stirring well with an equal volume of water and then diluting to the extent desired

3 MINERAL OIL-COCOANUT OIL

50-50 mixture by volume of mineral oil and cocoanut oil	60 pounds
Distilled red oil	8 pounds
Triethanolamine	3 pounds
Ammonia (14%)	5 pounds
Water	350 pounds

The Committee on Olive Oil Alternatives of the National Association of Wool Manufacturers has recommended the above formula for use in spinning The mineral-cocoanut oils, red oil, and triethanolamine are mixed, forming a clear blend, after which they are poured with constant agitation into water After emulsification, the ammonia is added for stabilization

Stearamide method. The main advantage of stearamide (or Duron) is that it forms a stable emulsion directly with neutral oils and is therefore particularly useful in the making of straight olive oil, peanut oil, or lard oil emulsion The following formula has been successfully used on a large scale:

Stearamide	60 pounds
Peanut oil	350 pounds
Ammonia (concentrated)	1⅓ quarts
Lecithin (antioxidant)	⅓ pounds
Water to make 100 gallons of emulsion	

The preparation of this emulsion is as follows 15 pounds of water and 60 pounds of stearamide are heated with constant stirring in a steam-jacketed kettle until an absolutely uniform paste is formed Special precaution is taken that the paste does not burn by shutting off the steam as soon as the paste along the wall of the kettle starts to turn brown With constant stirring, then, the whole amount of the oil is added in portions of approximately 50 pounds at intervals of three to four minutes When all of the oil has been added, the oil-stearamide mixture is a heavy, syruplike emulsion of an ivory color During the entire time of adding the oil, the solution is kept

at a temperature slightly below the boiling point Then the steam is shut off and cold water is added with constant stirring over a period of about ten minutes until the 100-gallon level is reached The mixing is continued for several minutes after which 1⅓ quarts of concentrated ammonia (25 per cent) is added and stirring is continued for two more minutes During the addition of the ammonia, the slightly yellowish emulsion will turn snow white The total time to make this emulsion is approximately one hour This emulsion formula is suitable for any blend in woolen spinning. For French worsted spinning, similar emulsions are made The concentration is 25 per cent for carding and combing, 15 to 16 per cent emulsion for drawing

Mixing implements The main mechanical operation involved in making an emulsion is the stirring procedure, of greatest importance in the formation of a good emulsion. Various speeds of agitation are necessary for the different types of emulsions Mechanical mixers and agitators for this purpose are made by various manufacturers and should be given preference over the still barrel or hand method. In the average mill a steam-jacket kettle with a central stirring device is employed. Other mills use live steam and circulate the emulsion through a pump system, forming the emulsion in this manner For emulsions of the highest stability and uniformity, colloid mills are used, but such a mill is rarely necessary for making emulsions for wool stock

Methods of Oiling the Stock

There are two main procedures for applying these lubricants to the stock oiling by hand and automatic oiling Oiling by hand is done with a sprinkling can, the oil being applied to each layer of stock as uniformly as possible after it has been laid It is then run through the mixing picker once or twice and allowed to lie for a short time, or overnight, to ensure thorough penetration. This method, while still used for small lots, is being rapidly replaced by automatic oiling methods, because of their labor-saving, material saving, and better control features Occasional cleaning of these devices is necessary, and they must be kept in repair.

As the stock is carried into the mixing picker by the feed conveyor, the wool oil emulsion is applied by one of the following methods:

1. *Gravity feed method* The simplest and crudest method consists of feeding the emulsion into a horizontal pipe that is fastened directly over the conveyor This pipe has holes drilled along its length from which the emulsion falls directly onto the stock passing below. The

disadvantage of this method is that it is very difficult to regulate and feed the emulsion uniformly onto the stock.

2 *English brush method* The emulsion flows directly through an oscillating pipe above a rotating brush roller Below the brush roller is a flipper bar that bends the bristles of the brush and causes them to spray the emulsion directly onto the stock One of these types is known as the Spencer oiler The Goddard oiler is very similar but is applied to bur pickers There is also a Sargent oiler, where an oscillating brush is used instead of a rotating brush In all cases the amount of oil put on the stock can be controlled quite simply, effectively and uniformly

3. *Drip method* A rotating drum dipping into the oil or emulsion carries it around to meet a series of drips across the width of the machine that guide the oil off the rotating drum and allow it to drip onto the stock

4 *Spray method* Here the wool oil emulsion is applied to the stock in the form of a fine mist by spray nozzles This is the best and most modern method of oiling In some mills where blends consist of wools of different colors, the stock is completely oiled in one passage through the machine but, to obtain more thorough mixing of the various colors, the stock may be run through the mixing picker two or three times

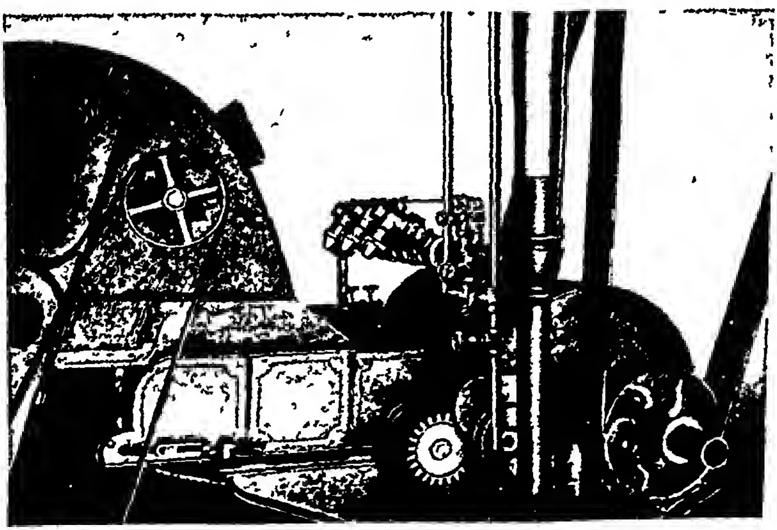


Fig 1 Parks-Cramer turbo-oil sprayer

Among the automatic methods of spray oiling there is the automatic oil sprayer shown in Fig. 1. This particular device is attached above the feed apron of the mixing picker, under which the mixed stock is fed Two to four nozzles can be used, depending on the number of times the wool mix is run through the picker. One woolen manufacturer, using a 48-inch Fearnaught picker equipped with three spray heads, can put through 1000 pounds of stock in two runs of thirty-five minutes each The corresponding capacities based on one hour of time are:

Dry wool treated per hour in pounds .	860
Emulsion used in pounds . .	358
Per cent emulsion by weight .	40
Gallons per head per hour	14½

The advantages of this automatic oiling of the stock are easily seen There is a saving of labor, thorough and uniform penetration of the oil, absolute permanent adjustment of the rate of delivery, and other favorable aspects

GARNETTING OF STOCKS

Whenever hard-twisted woolen, worsted, cotton, and rayon yarn or yarn wastes are to be employed in woolen mixes, it becomes necessary to subject the stock to a garnetting process as a succession to rag picking or teasing Garnetting has for its object the thorough breaking up of the waste and its return to a fibrous condition so that it can be used in mixes with virgin wool or other stocks. An ordinary waste card would not be satisfactory here, because much tearing, teasing, and actual breaking of the hard-twisted material is required, which ordinary card clothing could not survive. Garnetting opens the twist in the threads, completely, blends the fibers perfectly, and delivers the stock in a fluffy, opened condition ready for mixing

The machines employed for this purpose vary according to the type of stock processed. For soft-twisted yarn and yarn waste a one-cylinder garnett is, in most instances, sufficient Garnetts are built in units so that another breast or cylinder can be added, if required The material is fed to the machine by hand or by means of an automatic feeder, depending on the condition of the stock. If it is very lumpy or snarly, an automatic feeder may not be advisable As the stock enters the strong fluted feed rollers, it is subjected to its first coarse opening by means of a heavy, wire-covered, small cylinder or licker in. This tears the lumps into smaller lumps or pieces and passes the stock onto the circumference of small workers and strippers

After this initial operation the broken pieces are passed on to the first large cylinder, which is also covered with garnett steel wire, the points of which are sharper than on the licker in Sometimes a dividing roller is used between the licker in and main garnett cylinder to prevent chocking or accumulation on the licker in The main cylinder is provided with a series of 4-, 6- and 8-inch diameter workers and 4-inch diameter strippers, which have for their purpose the opening and straightening of the material Their wire teeth are of the garnett type and revolve so that the points of their wires are presented to those of the main cylinder without touching A fancy roller raises the material out of the cylinder so it can be picked up by the doffer, which rotates slowly and collects all the garnetted stock off the main cylinder If the stock is in good condition and opened with no piece of yarn left whole, it is rolled up in a lap or dropped on the floor

If this operation is not sufficient, a second cylinder can be connected and started up and the same process repeated until the stock has the proper soft and lofty condition and no pieces or lumps of unopened thread remain.

The production of such machines varies from 50 to 75 pounds hourly on average hard-worsted thread wastes. On softer stocks, of course, the production is higher The following combinations of sets are used in American mills·

1 Four-cylinder 30- by 60-inch breast garnett machine, for hard-twist waste

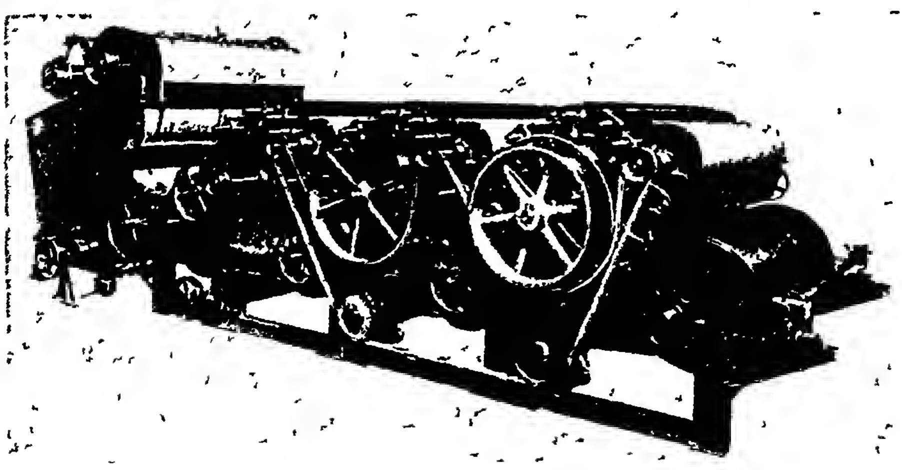


Fig 2. Three-cylinder breast-type garnett. *Courtesy Proctor & Schwartz, Inc*

2 Three cylinder 30- by 60-inch breast garnett machine with automatic feeder, for medium-twist yarn waste (Fig. 2)

3 Two cylinder 30- by 60-inch plain garnett machine with apron hand feeder, for soft rayon thread waste

The latest type for opening of hard-twist worsted threads is a duplex garnett unit which is two garnetts in one and is provided with an automatic feeder It delivers stock in a lap (Fig. 3)

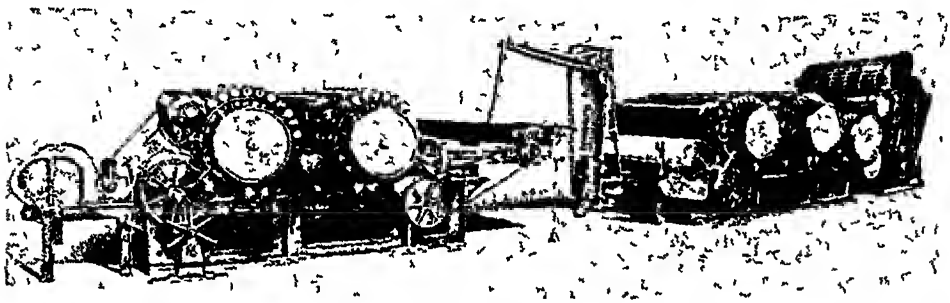


Fig 3 Duplex garnett unit *Courtesy Proctor & Schwartz, Inc*

Garnett wire Garnett wire is a long, wedge-shaped, steel ribbon with sections cut out as shown in Fig 4 The rolls to be garnetted are put in a screw-cutting lathe and a deep thread or spiral groove is cut the whole length of the roll Then the toothed wire is wound in this groove under tension and "staked in" or "caulked in" as shown in Figure 4

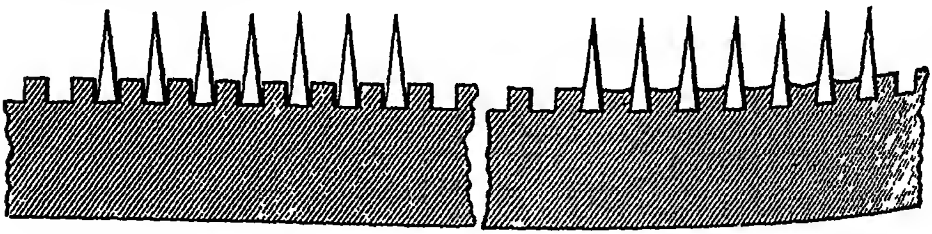


Fig 4 Enlarged section of garnett-wired cylinder

BLENDING OR MIXING MACHINERY

Under the heading of mixing pickers come many classes of machines that serve multitudinous purposes in accordance with the trade they are used in, such as straight woolen yarn manufacture, felt manufacture, novelty yarn manufacture, carpet manufacture, and so on, and also whether or not the type of stock requires a heavy or light type of picker It is not unusual in American mills for one

plant to have several types of pickers such as teasers, willows, bur-pickers, and fearnaughts rather than several of one type of machine

The function of the machine is principally to mix the stock, open it still further, and deliver it in the most suitable condititon to the woolen cards This is in most cases accomplished by means of a large, rapidly rotating cylinder provided with strong teeth or hooks bent forward or in the direction in which the cylinder rotates

The most efficient machine for opening, teasing, and blending the mixed and oiled stock is the mixing picker It is built heavily and strongly, so it can stand much abuse, is suitable for all types of stock, and meets all working conditions that arise in the average woolen mill

Primarily, the mixing picker consists of a feed apron made of heavy leather belts to which are fastened maple or beech slats with copper rivets or burs, driven by pulleys or sprocket chains The sides are built up sufficiently high to permit a heavy or high stacking of stock They are usually 36, 42, or 48 inches wide In place of the feed apron automatic self-feeders or hoppers can be used There are usually two pairs of large fluted feed rollers, or three fluted rollers and one pin-roller, or a single pair of cockspur rollers, and sometimes three cockspur rollers and one fluted The arrangement depends on the stock used for matted stock and fairly long staple, the three cockspur and one fluted rollers are recommended for short stock the single pair of cockspur rollers are preferred, also the pin feed roller and shell system can be used here

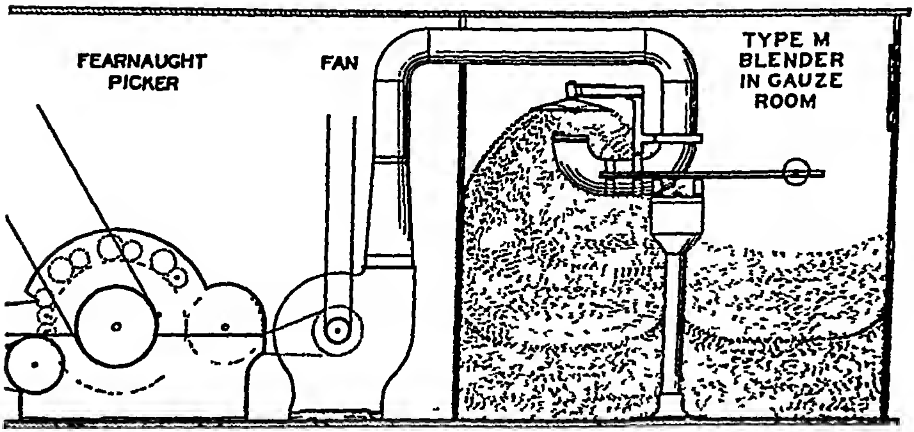


Fig 5 Diagram of combination with Truslow blender
Courtesy Curtis & Marble Machine Co

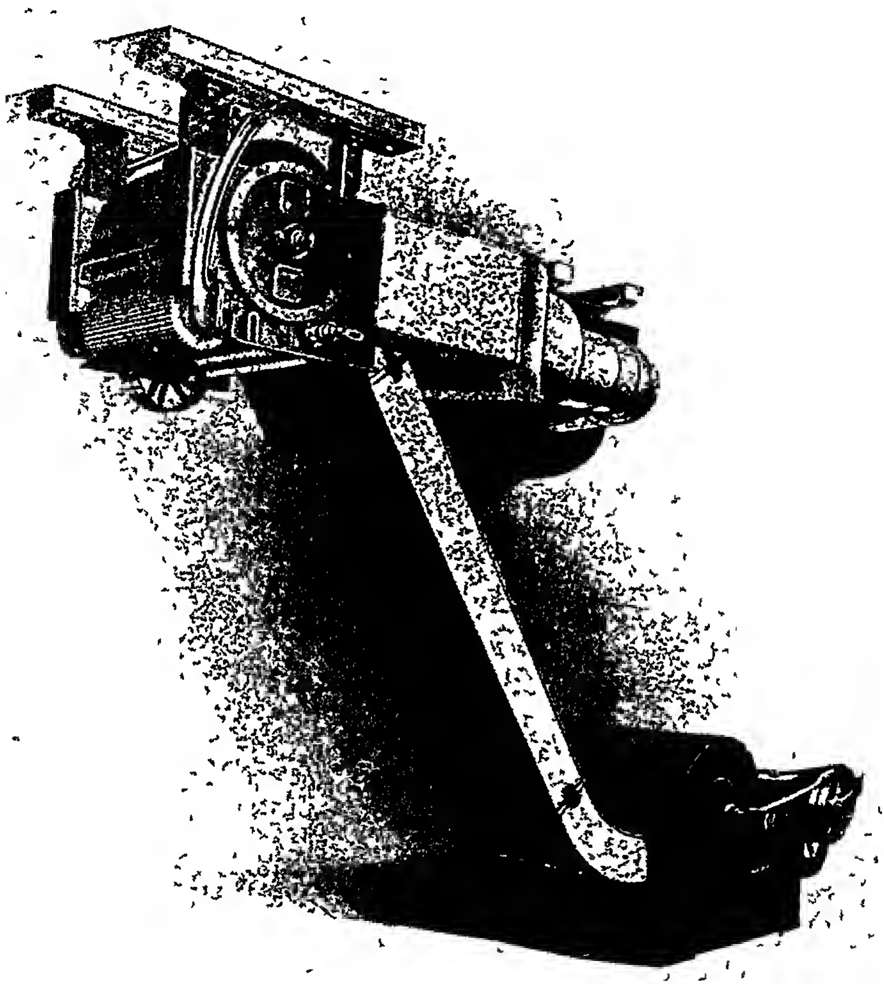


Fig 6 Mixing picker with ceiling condenser delivery
Courtesy Proctor & Schwartz, Inc

Heavy springs are provided above the feed roller bearings so that a heavy subdividing may be obtained by the action of the feed rollers and the main cylinder Automatic oilers built by various machine builders are all designed to fit over the feed apron and slightly ahead of the feed rollers

The delivery end of the various machines differs depending on whether the stock is to be dropped on the floor or into a truck, blown directly to the card stock bins, or taken to another mixing picker. Several of these arrangements are in common use One of these is shown in Fig 6. The Truslow patented blender has been introduced to

eliminate "rowy" goods and to secure more economical blending of all kinds of stocks Fig. 5 shows a combination of machines that has been used successfully on wool mixed with rayon, cotton, and shoddy of widely different fiber lengths and qualities.

For exceptionally cotted or matted stock or long carpet or worsted stock, or even ordinary woolen mixes for coarse numbers, shredders or fearnaught pickers are employed extensively. They are also known as Scotch pickers, tenter hook willows, etc They constitute an intermediate step between the straight mixing pickers and the garnett machine. The object of the fearnaught is the opening and mixing of the stock by a large rotating cylinder filled with cockspur teeth or hooks, which work in conjunction with smaller rollers known as "workers" arranged around the circumference of a large cylinder

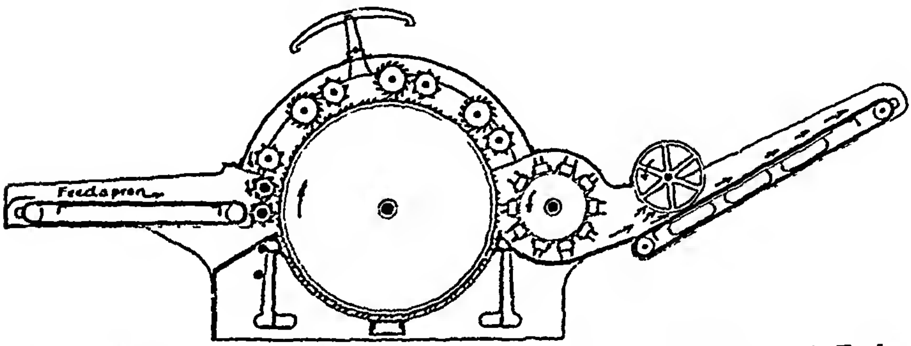


Fig 7. Elevation of an American fearnaught picker *Courtesy Davis & Furber*

The combined action of the two separates all hard or tangled bunches of wool and intermixes the stock thoroughly. The machine operates at slower speeds and does less damage to long stock because of a gentler action than the fast operating mixing picker. This machine is operated at not more than 225 r p.m. at 36 inch diameter and at not more than 175 r p.m. at 48 inch diameter. Its capacity for production is from 800 to 1,500 pounds of wool per hour. Fig. 7 shows such a fearnaught picker. This machine is provided with a condenser apron at the delivery end, designed to deliver the stock in lap form directly into a truck. The remaining details may be gleaned from the figure There are three pairs of workers and strippers provided with cockspur teeth intersecting each other on short stock, distinguishing it from the garnett machine On long stock the rollers are set further apart.

Continuous blending systems have come into vogue for economic reasons and, combined with a super picker, are highly flexible and

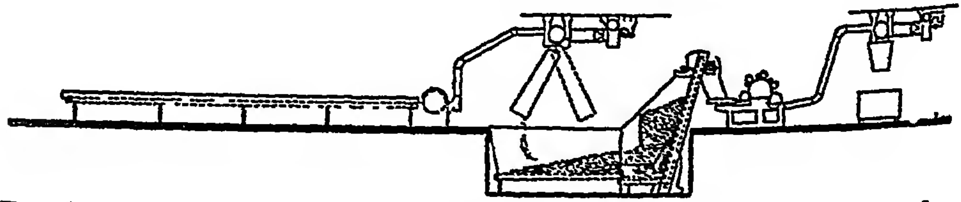


Fig 8 Continuous blending arrangement *Courtesy Proctor & Schwartz, Inc.*

quite automatic. Such a system is shown in Fig. 8 A production of 5000 to 6000 pounds per hour has been reached with this super picker and the continuous blending method.

Shredders and shredding pickers are extensively used in the wool reclaiming trade for shredding burlap, gunny sacks, sugar bagging, carpets, and similar tough materials If a woolen mill makes its own shoddy or reclaimed wools for its mixes, it is very likely to have some of these machines in the picking room These machines differ from the fearnaught in that they have no workers and strippers. They resemble the ordinary mixing pickers but are built much heavier, similar to the rag pickers or lumpers used in making shoddy All these machines have to stand considerable abuse and are required to handle all types of stock that may be needed by a woolen mill in making woolen yarns for anything from dress goods to plushes and carpets

WOOLEN CARDING

After the stock has been thoroughly mixed, oiled, and picked, causing a thorough amalgamation of all colors or different stocks required for the particular yarn to be made, it is submitted to a carding process. In no previous process or operation has such a thorough attempt been made to open, separate, or straighten the individual fibers of the stock.

Woolen carding has for its principal objects.

1. Further to open the stock as a whole.
2 To disentangle locks and bunches
3 To straighten the individual fibers as far as required
4. To remove natural impurities, i e, shives, fly, burs, and dust
5 Further to mix the stock and its component parts
6. To deliver the stock in convenient form for transfer to next card or spinning machine such as lap, or roping.

These objects are accomplished satisfactorily by the three-card system generally in use in American mills. In this respect woolen carding differs from worsted carding, which is a one-card system. Although the main object of worsted carding is to lay the wool fibers

parallel to each other, no such attempt is made in woolen carding This is the fundamental difference between the preparation of a woolen yarn as compared to a worsted yarn or combed cotton yarn The fibers in a woolen yarn lie in every direction, whereas in a worsted yarn they lie parallel to each other to a marked degree

Function of the Card Wire

The card wire on the various rollers of a card perform different functions, depending upon in what direction the roller turns, in what direction its wire points, and how fast it travels in relation to other rollers Three kinds of effects can be attained by a variation of these facts, namely:

1. Wires arranged "point against point," i e, *carding*, as in Fig 9
2. Wires arranged "point against back," i e, *stripping*, as in Fig 10
3. Wires arranged "back against back," i e., *raising*, as in Fig 11

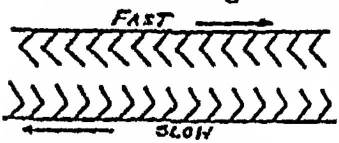


Fig. 9 Carding action
Point against point
Opposite direction

The relative surface speed of the rollers plays an important part in the proper functioning of these effects and in obtaining the results desired In a card every one of three actions occurs at every point of contact or working points between the rollers, i e, carding or working the fiber, stripping or removing fiber; raising the fiber or brushing it up to the surface of the wire

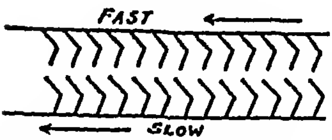


Fig. 10 Stripping action
Point against back
Same direction

Carding (Fig. 9) takes place when the wire points of the main cylinders, traveling at high speed, bring the wool in contact with the wire points of the slower moving workers or doffers This a "point to point" action, essential in opening the tangled wool fibers

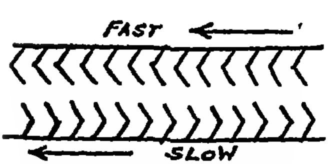


Fig 11 Raising action
Back against back
Same direction

Stripping (Fig 10) takes place when the wires of the workers meet the points of the strippers in a "point to back" action This arrangement is used to remove the wool from the workers and put it back onto the main cylinder wire A special stripping action takes place without a carding action, when the angle stripper

on a worsted card transfers the wool from the doffer to the second main cylinder.

Raising (Fig. 11) takes place when the long wires of the fancy reach into the short wires of the main cylinder, brush the wool fibers to the surface of the main cylinder, and permit the doffer wire to transfer it. This is a "back to back" wire action and is done at high speeds The density of the wire and the correct surface speed of the two rollers must be continuously maintained to be effective.

Principle of Carding

There are two main principles involved in carding generally First comes the carding proper, that is, the opening of the wool through rotating cylinders or rollers covered with card clothing that is provided with wire teeth working *point against point* and rotating in the same direction This action takes place between the main cylinder and the workers, the workers taking the wool from the cylinder. The actual carding takes place at the point at which main cylinder and workers have the closest approach but do not contact. The wire teeth of the main cylinder carry the wool on their surface, thus, where it projects, the wool is readily caught by the clothing of the worker. Since the wool is taken away slowly against resistance the fibers are straightened and opened in this process.

In this way the wool is deposited on the wire teeth of the worker, which revolves slowly and brings the carded wool around to the stripper, a smaller, fast-running roller This concerns the second principle in carding, namely, stripping Stripping involves the removal or transfer of the carded stock from the cylinder or roller that has performed the carding. It occurs when the points of the card wire on one cylinder work against the backs of the teeth on the other. The clothing of the stripper roller works with its points against the backs of the wire on the worker, thus gently lifting the carded wool from the worker. Stripping is essentially a transfer of the stock from the worker back to the main cylinder, the teeth of which work with their points against the back of the stripper teeth at a velocity in excess of that of the stripper. The stock is now carried forward to the next pair of workers and strippers, which are set closer and closer to the main cylinder, and the same action is repeated every time. The object of having six to eight pairs of these workers and strippers is to divide the work between them and to give the stock repeated carding—a thorough opening and straighten-

ing of the tangled mass of wool fiber Some stock may pass around the cylinder several times before it is caught by a worker. Much depends on the proper setting of the rollers, their perfect circumference or trueness, the condition of the wire, the kind or size of the wire, and the speed of the rollers

Carding constitutes the last operation or process in which the wool fibers can be properly opened It is considered by many just as important a process as spinning, because a good even woolen yarn cannot be spun from an uneven, improperly carded roving. Roving, or, as it is more commonly known in American woolen yarn manufacture, roping, is a ribbon of carded wool, the fibers of which are rubbed together into a round continuous strand with no twist whatever, ready for the spinning process Previous to this stage the round continuous strands of carded wool as they are formed on the cards are known as card sliver, or lap, which has no twist either

From the early days of hand carding the technique rapidly advanced to the roller or cylinder card introduced in the United States by Arthur Scholfield about 1793 It was a wooden affair about 25 inches wide with a cylinder diameter of 33 inches It carried two workers and strippers, a fancy, and a 14-inch doffer covered with card clothing sheets. A fluted cylinder of 13-inch diameter was arranged behind the doffer A board, acting as a comb, brushed the web from the doffer in the form of sheets Carried along by the fluted wooden cylinder behind the doffer, these sheets were made into rolls by a press board set close against the fluted cylinder and arranged underneath Dropped into a pan, these wool rolls were then pieced together and spun into yarn on the "billy" and the "jenny".

This is a far cry from the modern American system of woolen carding, which is done by means of the so-called three-card system, termed in succession, the first breaker or scribbler, the second breaker or intermediate card, and the finisher or condenser card This is commonly known as one set of woolen cards, the units by which the size of woolen mills in the United States are gauged A good-size woolen mill has about twenty sets of cards

The three successive machines do not differ in construction or action, but only in the fineness of the card clothing and the way the product is delivered. They generally consist of the following modern setup.

1 Automatic hopper self-feeder, single cylinder breast or burr works, regular one-cylinder cards with workers, strippers, and a doffer, the stock being delivered in sliver form

2 Intermediate sliver feeder and two single-cylinder cards coupled

together (second breaker and finisher card), with a tape or triple-apron condenser delivering the roping on two or more 40-end spools

This constitutes most modern American carding practice, but other arrangements are used in the trade One very common arrangement is to have three distinct cards arranged in direct sequence, i e , breaker, intermediate, and finisher cards, connected by automatic feeding devices.

Table 4 shows the types and sizes of woolen cards in place in the United States in 1943 and is taken from *Facts for Industry*, October, 1945.

TABLE 4 UNITED STATES WOOLEN CARDS IN PLACE IN 1943

Type of Card	*Number of Cards and Cylinder Sizes*					
	Total	*48" x 48"*	*48" x 60"*	*60" x 48"*	*60" x 60"*	*All Others*
*Woolen cards, total**	5,221	1,208	1,494	421	1,326	545
One-cylinder	227	—	—	—	—	—
Two-cylinder, total	784	254	212	36	181	101
Ring doffer type†	589	202	197	36	112	42
Tape type†	195	52	15	‡	69	59
Three-cylinder, total	3,526	855	1,179	296	804	392
Ring doffer type†	2,111	712	721	169	285	224
Tape type†	1,415	143	458	127	519	168
Four-cylinder, total	684	99	103	89	341	52
Ring doffer type†	279	87	39	62	70	21
Tape type†	405	12	64	27	271	31

*Shoddy cards are not included †Of the two-cylinder cards, ring doffer type, 92 per cent were under 60 ends, tape type, 49 per cent were under 60 ends Of the three-cylinder cards ring doffer type, 77 per cent were under 60 ends, tape type, 60 per cent were under 97 ends Of the four cylinder cards, ring doffer type, 55 per cent were under 60 ends, tape type, 70 per cent were under 97 ends. ‡Included under "all others" to avoid disclosing data for individual plant

Automatic Feeders

The purpose of automatic feeders, particularly as used in connection with cards, is to deliver properly prepared stock uniformly into the primary processing machine, thereby eliminating the necessity of constant attention by an operator Since uninterrupted output is essential in a carding machine, old hand-feeding methods have long since been entirely replaced by the Bramwell feeder and by automatic feeders of a generally similar nature.

The prepared stock is placed by hand in the hopper, which may either be V-shaped or else substantially cubical with a bottom carrier apron, as is most commonly found in modern feeders. The supply of stock in the hopper is gently pressed by gravity or the forward

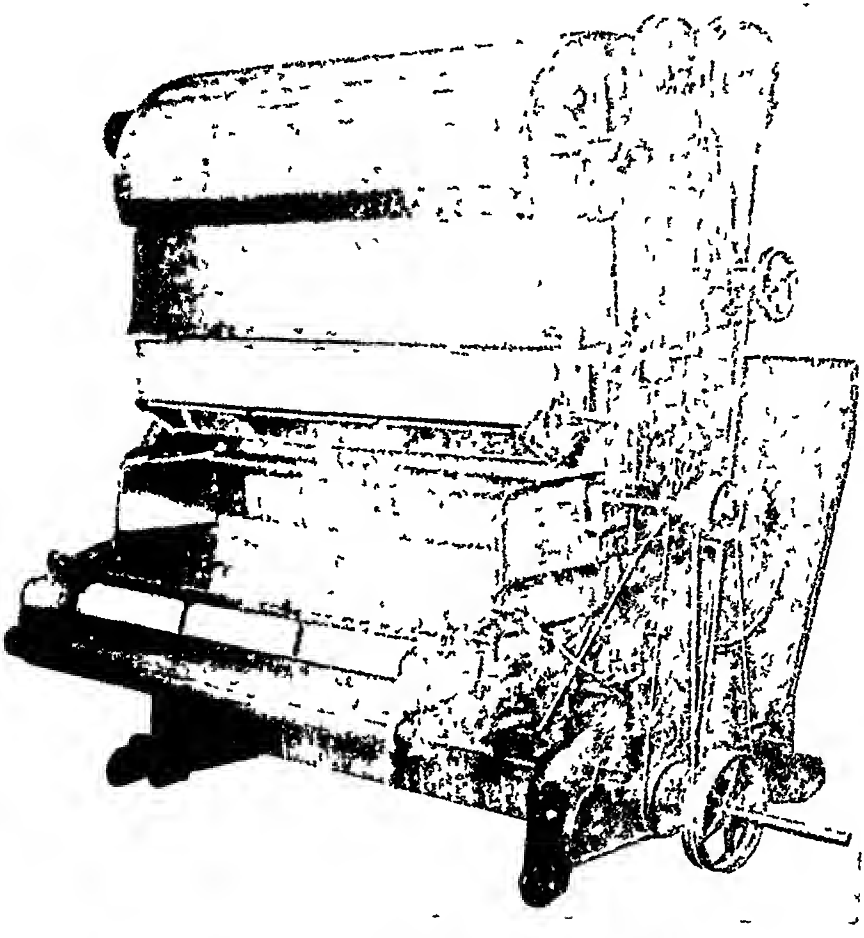


Fig 12 Automatic Bramwell woolen card feeder
Courtesy Geo S Harwood & Son

motion of a bottom apron against the lifting surface of a spiked apron composed of hardwood slats studded with upward pointing tapered steel pins Various auxiliary means are generally provided for keeping the hopper's contents of a uniform density or for pressing them with uniform effort against the spike apron so as to compensate for changes in the amount of material therein owing to gradual depletion and sudden replenishment

A reciprocating comb works against the lifting surface of the spike apron to prevent delivery of excessively large lumps of stock

and to spread the stock evenly over the full pinned width of the apron After passing the comb, therefore, the stock is loaded to a uniform depth on the surface of the spike apron in accordance with the particular spacing between their working surfaces as adjusted for each run of work The spike apron thus carries an evenly distributed load up over its top driving roller and then downward toward the front of the feeder, where one of sev d to strip the stock from its now downwardly poin

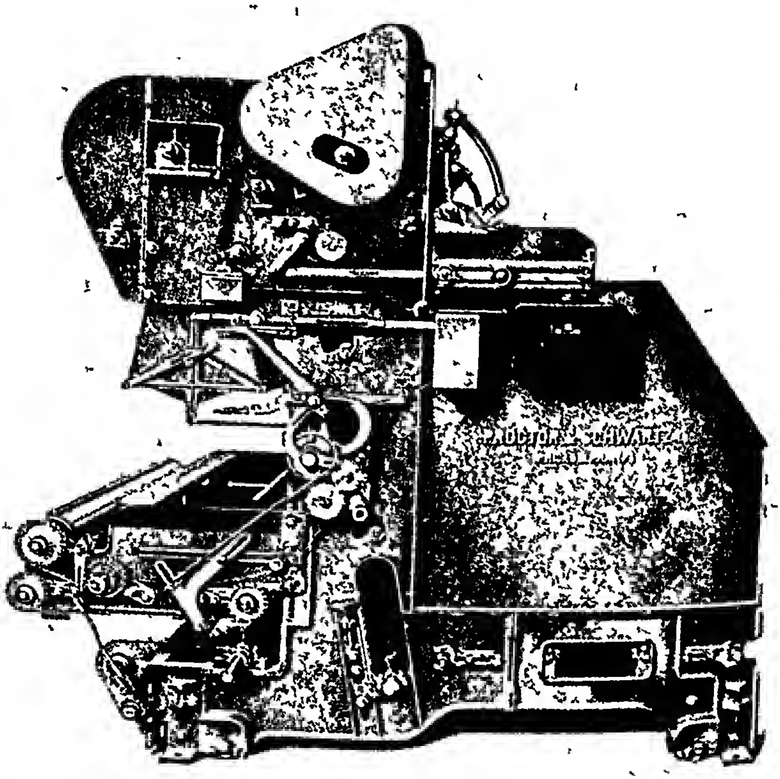


Fig 13 New Proctor automatic card feeder *Courtesy Proctor & Schwartz, Inc*

For short-to-medium staple stock a wipe apron or cylindrical beater equipped with leather tipped lags is used as a stripping device, whereas a multipinned convex comb working against a stationary concave pinned board is regularly employed for long staple stocks In either case the stock is stripped into a scale pan supported on pivotally mounted counterbalance arms with adjustable weights so set that the entire assembly automatically overbalances when the proper

amount of material has been stripped from the spike apron into the scale pan This overbalancing motion instantly causes the spike apron to stop, thereby preventing further stock from reaching the scale pan At predetermined regular intervals ranging from 30 to 90 seconds, depending upon the kind of work being run, drop doors in the bottom of the scale pan are tripped open so as to dump its contents onto the plain delivery apron of the feeder The doors are thereafter immediately closed by an automatic motion that also resets the entire scale mechanism into the weighing position and starts up the spike apron to begin a fresh weighing cycle This process is continuously repeated

While each weighing of stock is being prepared, a pushboard moves forward to even off the rear edge of its predecessor as the delivery apron carries it under a paddleboard smoothing device toward the feed rollers of the card The pushboard recedes to its starting position just in time for the next dumping of stock from the scale pan to occupy the entire space between itself and the preceding dumping Thus a continuous succession of identical scale weighings are delivered in the form of an unbroken mat of stock to the feed rollers of the first breaker card.

First or Breaker Card

As the name implies, the function of the first or the breaker card is to do the preliminary rough work on the woolen stock The first breaker card generally is built in 48 or 60 inch widths with a main cylinder of 48 or 60 inches diameter and 30 or 36 inch diameter doffers with six to eight pairs of workers and strippers (See Table 4) A typical sectional elevation is shown in Fig 14 of a three-cylinder set of 60 by 60 inch woolen cards equipped with automatic feeders, metallic breast, first breaker card, intermediate Scotch feeder, and angle stripper, delivering to a four-bank tape condenser, this is a very common American setup for the general production of woolen yarns

Bur cleaning breast Quite often as a precaution, particularly on especially rough stock, very dirty, burry, or hard stock, it is advisable to use a metallic breast right after the feed rollers on the first breaker The metallic breast has for its purpose the breaking up of all lumps and hard bunches that may be present in various mixes and the correct preparation of the stock for the first breaker. Such an arrangement pays for itself in the saving of the card clothing on cylinder and workers It is an individual unit, is interchangeable and, if not required, can be removed entirely. The metallic breast is usually

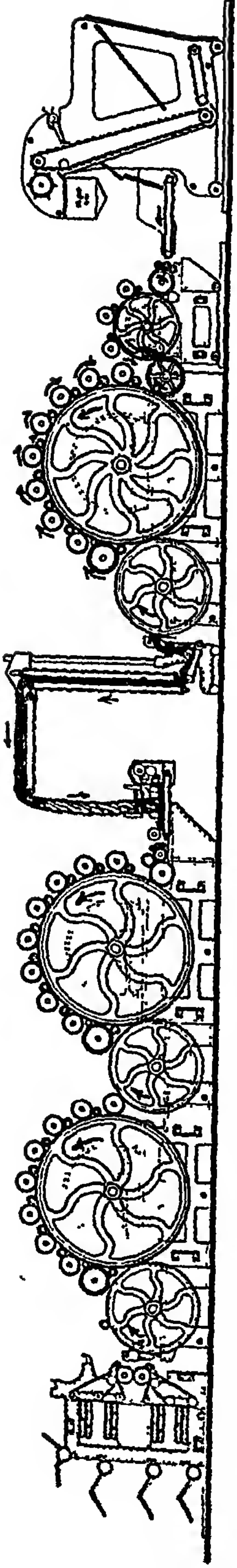


Fig. 14 Three-card woolen set with center-draw ribbon transfer, automatic feeder, and condenser *Courtesy Whitin Machine Works*

built and furnished separately by all card builders. The one illustrated in Fig. 14 happens to consist of a tumbler or licker-in breast cylinder, and three pairs of workers and strippers It is the standard for short-to-medium-length stock free from burrs Other arrangements, however, are possible depending on the nature of the stock.

If a stock is particularly burry, it becomes necessary to alter the breast to permit the mechanical removal of the burrs, shives, chaff, etc , at this point The breast is also useful in removing dust from carbonized stock A very common arrangement of a special burr cleaning breast on woolen breaker cards is shown in Fig 15

This arrangement consists of feed rollers, a brush, breast cylinder provided with two workers and strippers and one burr guard, followed by a brush and a burr cylinder with another burr guard, then the tumbler and main cylinder This burr breast is covered with garnett wire and has two places where burrs, slivers, and chaff fall into a pan or tray

These burrs have the shape of small peas, soft and grown in spirals of prickly matter, which unwind to several inches in length. The burr-cylinder blades rotate against the points of the card wire and are set close to them without touching, knocking the burrs bodily out of the stock into the pan.

This is a very effective means of burr removal, where they occur in moderate quantities in the stock For complete removal of burrs and other vegetable matter occuring in large quantities the ~~chemical method of carbonizing is used~~ as described in Chapter 9. When not required these burr cylinders or beaters can be set away from the burr cylinder, thus becoming inoperative.

Whatever form or construction the breast

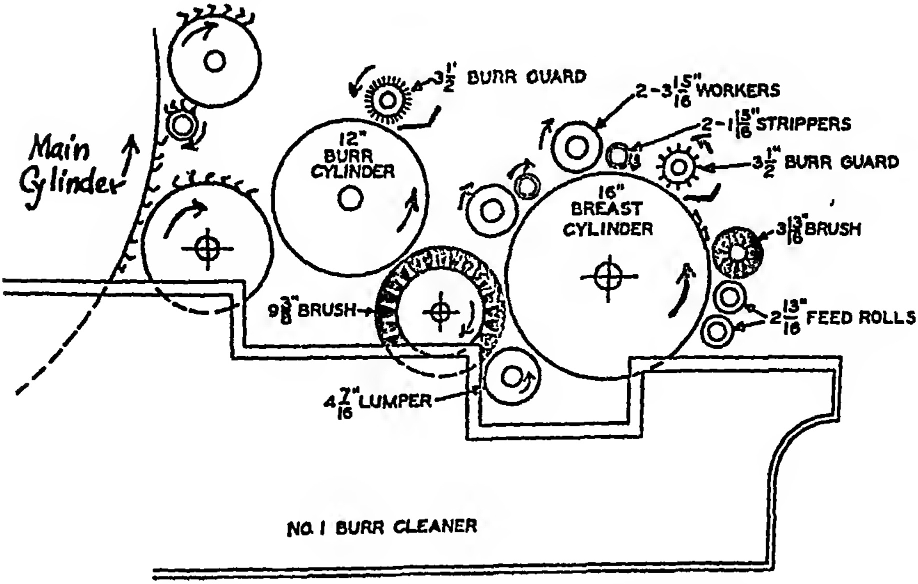


Fig 15 Details of bur breast on the first breaker card
Courtesy Davis & Furber Machine Co

works (as it is sometimes called) takes, it performs the same operation, to a greater or lesser extent, depending entirely on the character of the stock A breast is a valuable adjunct to a breaker card and is found in most modern woolen mills A breast works helps to clean and break up the stock, accordingly preventing damage to expensive card clothing, lessens the load on the breaker card, and produces a better spinnable stock. (See Figs 4 and 16)

This garnett or bur breast is connected in most instances by a tumbler to the main cylinder of the breaker card, usually 60 inches in diameter and 60 to 72 inches wide The main cylinder is provided with eight pairs of workers and strippers, made of aluminum for lightness and ease of handling The workers are usually 7¾ inches in diameter and the strippers are 3½ inches in diameter The worker takes the wool from the carding surface of the main cylinder on the one side and the stripper strips it off the worker and passes it back to the cylinder This is the point where the real carding action, i e, the separation of fiber from fiber, takes place The workers move very slowly, whereas the strippers rotate rapidly The main cylinder workers, and strippers are covered with wire clothing, which

GARNET WIRE

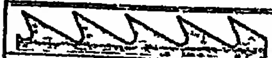
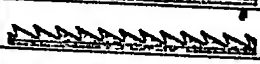
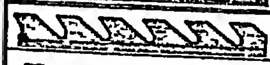
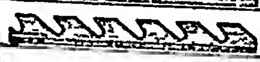
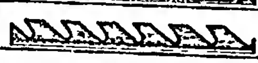
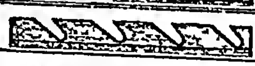
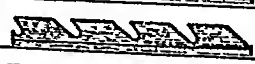
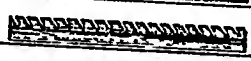
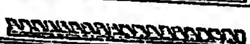
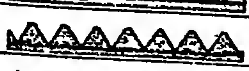
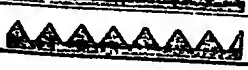
SAMPLE	SIZE	STYLE OF WIRE	SIZE OF WIRE	THICKNESS IN .000	FEET PER LB	THREADS PER INCH	
	#1	LICKERIN WIRE	#6	.080	28	4	5
	1A	" "	,	"	27	"	"
	2	" "	10	055	49	5	8
	3	" "	11	043	66	8 9	10 12
	4	" "	12	035	93	12	14
	5	" "	14	.028	141		"
	6	" "	15	020	186	16	18
	7	" "	"	017	233		"
	2	BURR WIRE SHORT TOP	10	055	44	5	8
	3	" "	11	043	60	8 9	10 12
	#3A	BURR WIRE SHORT TOP	11	.043	60	8 9	10 12
	4	" "	12	.035	80	12	14
	6	" "	14	.020	155	16	18
	2	BURR WIRE LONG TOP	10	.055	40	5	8
	3	" "	11	.043	55	8 9	10 12
	4	" "	12	.035	75	12	14
	6	"	14	.020	147	16	18
	10	" "	13	.033	73		14
	10A	" "	15	.039	106		"
	1	V WIRE	6	.080	22	4	5
	2	"	10	.055	54	5	8
	3	" "	11	.043	70	10	12

Fig 16 Details of garnett wires

perform the carding action The type of wire covering, the direction in which it points, and the direction and the speed of rotation are

carefully co-ordinated to prevent damage to the stock The direction in which the wire points is indicated in Fig. 15, as well as the direction of rotation of the various units

The fancy The stock on the main cylinder, after it has been thoroughly carded repeatedly, becomes fluffy and voluminous It is the function of the fancy to raise the carded fibers to the top of the wires of the main cylinder It is neither a carding nor a stripping action. Whereas the wire of the main cylinder, workers, and strippers is short, the wire of the fancy roller is long and is set to reach slightly into the card clothing of the main cylinder. Of course, the surface speed of the fancy is in excess of that of the main cylinder, so it can raise the stock to the points of the wire on the cylinder and subsequently be removed by the doffer The fancy is a roller 10 or 12 inches in diameter, enclosed in a hood and revolving at 900 to 1,200 r p m Careful setting of the fancy is essential to accomplish its purpose to the best advantage of the stock with minimum wear and tear on the wire

The doffer On the first breaker card the doffer takes the raised and carded stock from the main cylinder as a uniform web deposit on its wire surface, and gets it ready to be doffed or removed by the doffer comb The doffer is usually 24, 30, 36, or even 42 inches in diameter, and rotates very slowly so as to accumulate a fiber web of sufficient weight to hold together and make a substantial weight sliver that will stand transfer to the next card The doffer brings the deposited stock around to the doffer comb, which dabs it off through fast oscillations, permits it to be gathered into a rotating tube or funnel, formed into a sliver or band known as card sliver, and passed through a pair of drawing-off rollers onto the next card or into cans provided for that purpose

The question of wider cards, i e, 72 inches and even 80 inches, has been discussed a great deal In Europe and in a few mills in the United States, these wider cards have been used Without increasing the speed, a 72-inch card produces 20 per cent more and an 80-inch card 40 per cent more roving than a 60- by 60-inch standard American card With the introduction of aluminum workers and strippers, and with higher wages, and particularly with the need for greater production, it may be necessary to go to wider cards

Card Clothing

Card clothing or wire clothing is the material with which the wooden or iron rollers, such as main cylinder, workers, strippers, doffers,

and fancy, are covered to provide a surface for the action of carding the wool stock Card clothing consists of wire teeth set in leather or combinations of cloth, rubber, felt, and wool, and bent to a uniform angle, all pointing in the same general direction Such card clothing is furnished by card clothing manufacturers in two varieties· (1) fillet clothing, and (2) sheet clothing.

Fillet clothing, often called "filleting," is made in narrow, continuous strips anywhere from ½ to 3 inches wide and any desired or ordered length Dimensions depend on the diameter of the roller to be covered and the clothing is wound spirally and continuously around the roller Fillet clothing can be used on practically all parts of the cards, whereas sheet clothing is primarily used on main cylinders only A leather foundation or base is generally employed for sheets, doffer rings, fancies, and feed rollers Although rubber is superior to all other kinds of foundations, its cost often prevents it from being used Other foundations are made in great variety and combinations such as Flexifort, rubber face, felt face, wool face, and cloth Rubber-faced card clothing is used where no emulsions are used in the stock.

Wire details Aside from the foundation, there are a number of details regarding the wire used that deserve careful consideration, namely· size of the wire, its arrangement in the foundation; its character and composition, angle of the wire in the foundation, and, angle at the bend

There are no set rules for the size of wire and its selection depends a good deal on the type of stock and machinery as well as the speeds used The stock has to be opened gradually, hence the clothing in the card will be coarse at first, getting finer as the carding process progresses Each main cylinder is, therefore, finer than the one before it The workers, strippers, and doffers have commonly the same number of wire as the main cylinder in each card, although some carders prefer the stripper wire to be a little coarser Fancies are of two types, the straight tooth and the low bend With the straight tooth, wire of two to four numbers coarser than that used on the cylinder is used on low stock, especially on the first and the second breakers For medium stock, wire of low-bend fancies is generally two numbers coarser than for the cylinders of first and second breakers Finishers usually take fancy wire the same size as the main cylinder's. Tumblers usually take the same or perhaps one number coarser than the cylinder's Licker-ins on woolen cards are made any number from double convex 15 by 20 up to No 28 diamond point

Most of these wire requirements apply to worsted as well as to

woolen cards On a worsted card the process is continuous and each roll is made finer than the last, the doffer often being one number finer than the cylinder For instance, a two-cylinder card with breast for medium work might have No 30 wire on the breast, No 32 on the first cylinder, No 33 on the first doffer, No 34 on the second cylinder, and No 35 on the last doffer, etc

Card clothing is set with different kinds of metallic wire such as iron, steel, tempered steel, brass, tin, and so forth The best wire for woolen carding is tin- or cadmium-coated tempered steel, which is springy and elastic, hence not easily bent out of place Wire is made round, elliptical, triangular, and diamond pointed, its choice depending largely on personal experience and preference

There are three gauges used in determining the number or size of card wire, namely, the American (Brown & Sharpe), the English or Birmingham, and the French gauge Table 5 compares the card wire in these three gauges

TABLE 5 COMPARISON OF CARD WIRE NUMBERS

		Nearest Equivalent	
Diameter Inches	*American Gauge No*	*English Gauge No*	*French Gauge No*
035	20	20	3
028	22	22	7
023	24	24	9
020	25	25	10
018	26	26	12
017	27	27	14
016	28	28	16
015	29	28½	—
014	30	29	18
.0135	31	30½	20
013	32	31	22
011	33	32	24
010	34	33	26
0095	35	34	28
.009	36	34½	28½
0084	37	35½	30

The card gauges used by carders in adjusting the distances between wire-covered rollers are also based on the same system They usually consist of a group of four to eight metal blades fastened together that resemble a closed 2-foot rule, 10½ inches long by 1½ inches wide The blades are of varying thicknesses such as No 22, 24, 26, 28, and 30 American gauge.

Counts and crowns. A few words explaining the English system of counts and crowns might be of interest. In the "counts and crowns" system 120-10 means 120 counts, 10 crowns, and twice the product or 2,400 equals the points in 5 square inches. This is the same for both sheets and fillet and for all systems In sheets the crowns in the above fraction are the number of backs in two rows of 1 inch or one row of 2 inches In fillet the crowns in the above fraction are the number of backs in one nogg or repeat for 1 inch. In sheets the counts for the above fraction are one-half the number of wires in 5 inches down the sheet In fillet a count and a nogg are the same, and the counts for the above fraction are the number of repeats in 5 inches

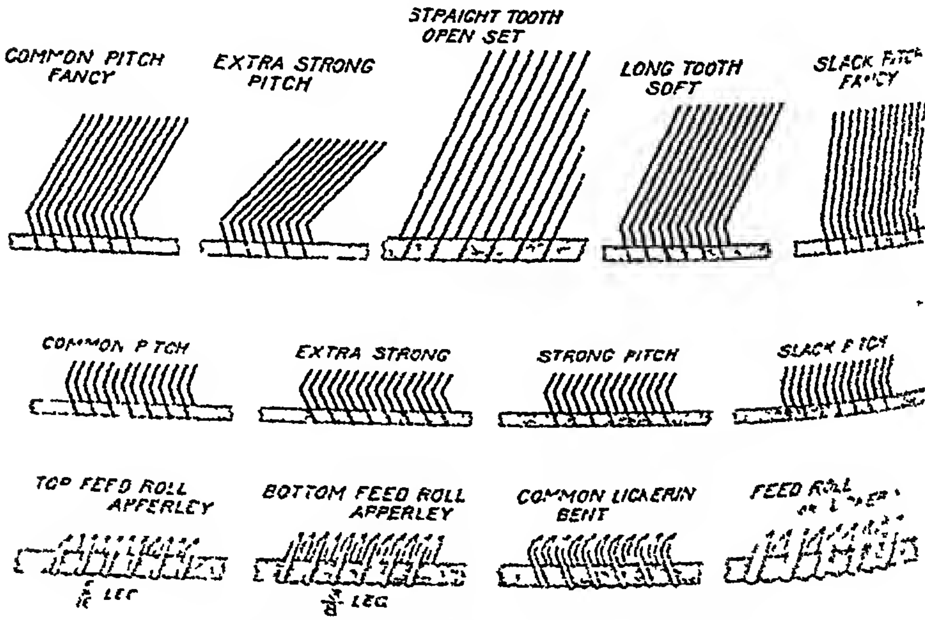


Fig 17. Various types of American card wires.
Courtesy Davis & Furber Machine Co

The wires are placed through the foundation by a machine that cuts the wire and bends it in the form of a staple ⊔, pierces the holes in the foundation, forces the staple through, and then creates the knee or forward angle. The teeth or staples are not forced straight through the foundation but at an angle that varies with the type of wire and its use on different parts of the card. The various angles

and the types of wires used for fancies, workers, cylinders, strippers, doffers, and breast works are shown in Fig 17

The staples are set into the foundation so that their crowns, i e, the bottom part of the wires, are either (1) plain set, (2) rib set, or (3) twill set

These terms apply to the arrangement of the crowns in the foundation By *plain set* is meant that the crown of the wire teeth overlap in the same way bricks are laid This method is not common in the United States By *rib set* is meant that the teeth are so inserted through the foundation that the crowns form ribs on the back running lengthwise of the fillet By *twill set* is meant that they are set in diagonal lines like the twill in a woven cloth Sheet clothing is generally *plain set* but most filleting is *rib set* or *twill set* (See Fig 18)

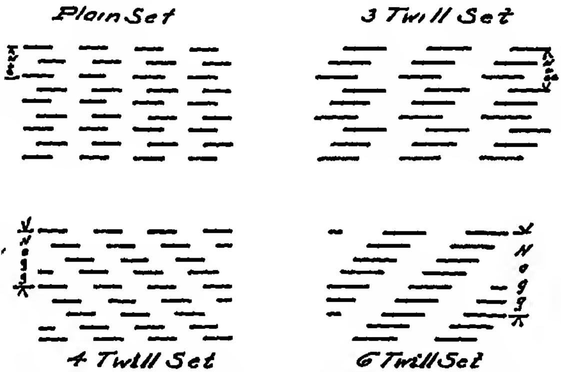


Fig 18 Settings or groupings of wire staples

The best way to order clothing is to specify the foundation, the number of the wire, the width of the card on the wire, and the diameter of the roller to be covered, together with any special directions such as "straight tooth open set," etc As a rule it is much better to leave the setting of the wires to the discretion of the manufacturer who has had such a long experience that he usually knows what is best for the work in hand If the points of the wire are too open the stock will not be sufficiently carded If they are too close or too dense the stock will be rolled up instead of opened out

Cylinder speeds The production of a card is indirectly affected by the speed of the cylinder Its speed depends directly on the rate at which the stock is fed into the card The cylinder speed, as well as the production of a card, i e, the amount of stock that can be properly carded, are dependent on the grade of stock handled, the size of yarn to be spun, and the nature and finish of the fabric to be produced Card-speeds, therefore, cannot be fixed arbitrarily Although it is customary to run main cylinders on all kinds of stock at approximately the same surface speed (about 1,150 feet per minute) variations will be found of good advantage in many cases

Intermediate Stock Transfer Devices

The product of the first breaker card must now be put into a transferable condition, which varies with the mill or with the equipment available for this purpose There are a number of these systems in use Different mills use different systems, depending on the preference of the foremen, on special manufacturing requirements, or on the equipment in present use These stock transfer systems are

1 Side balling machine (Torrance).
2 Apperly side drawing
3 Center draw Scotch feeder.
4 Belgian lap system.
5 Diagonal broad band feeder.
6 Blamire lap former.
7 Scotch cross feeder

All these systems have particular advantages under given mill conditions, but all of them aim at the one or more objectives pertinent to such manipulation of the stock, which are·

1 Putting the stock into some convenient form for transfer
2 Mixing the stock with that of other cards.
3 Making the transfer as rapidly as possible
4 Serving to lay the fibers in a different position than when they left the breaker card.
5 Feeding a definite, known quantity to the intermediate card or the finisher card.

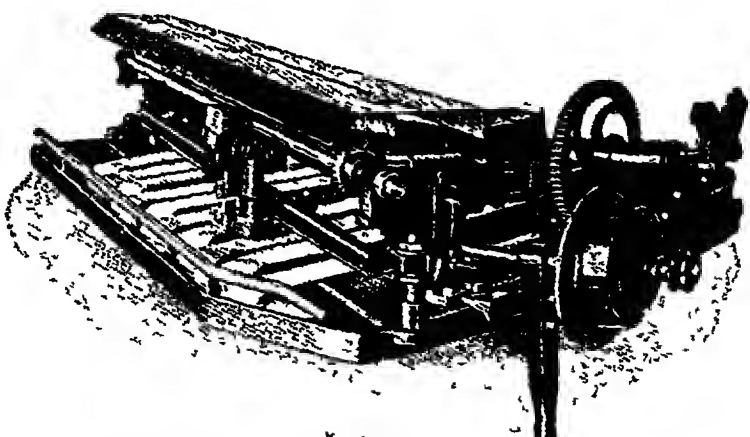


Fig 19 General view of Harwood Apperly intermediate card feeder

In all these methods of transfer, these objectives are upheld and followed as far as possible In the United States a common system is the Apperly diagonal feeder, which is practically automatic and does much to mix the stock again. (See Fig. 19)

In older days the lap system and hand feeding were in common use Among these systems were the above-mentioned Blamire lap former, which is especially adapted to very short-fibered stock. After the material is stripped from the doffer, it is carried forward by a lattice and delivered onto a lower lattice through rollers and then wound into a lap. The thickness of the wad or the number of doublings are regulated by double-action, racking motion Two or three laps from this machine are then fed to the succeeding card

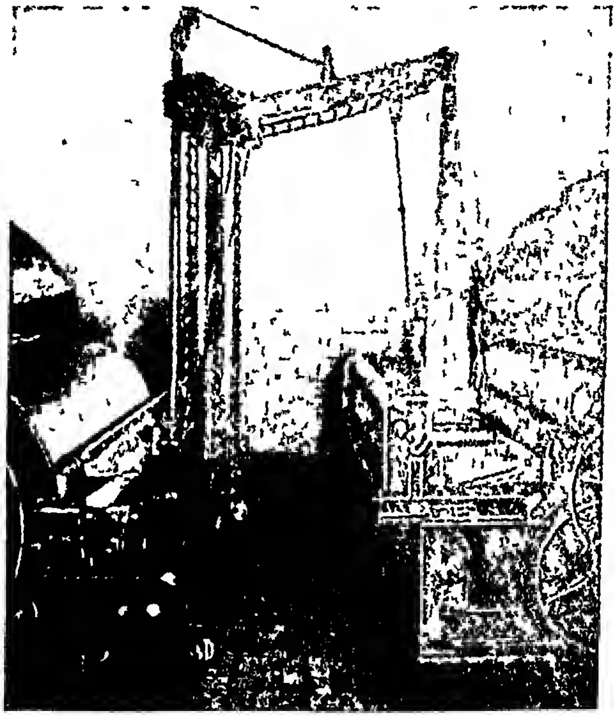


Fig 20
Whitin center-draw Scotch intermediate feeder.

The old Belgian system, used to some extent by woolen spinners in New England, was deemed particularly effective in getting uniformity of intermediate card feeding Here the web was wound continuously for hours onto the circumference of a large wooden drum When a certain time had elapsed the lap was cut across and weighed carefully. Its position was then changed and fed into the intermediate

The old Torrance balling head had for its purpose the winding of the side drawing from the first breaker into flat balls, which were placed in a creel and fed to the second breaker This is similar to the Platt & Richardson balling machine and its advantages are that a larger number of ends can be fed to the second breaker. The larger

the number of slivers that are fed to the intermediate, the more even the slivers will be and the more thorough the blending of the stock and the more even the delivery.

The new automatic Apperly or Whitin center-draw Scotch or the diagonal broad band or sliver feeders are preferred in modern plants In this category two types are common, one for shoddy, short wool blends, where a sliver would not be strong enough to support its own weight and the Apperly diagonal sliver feed, for stock that is strong enough to support its own weight.

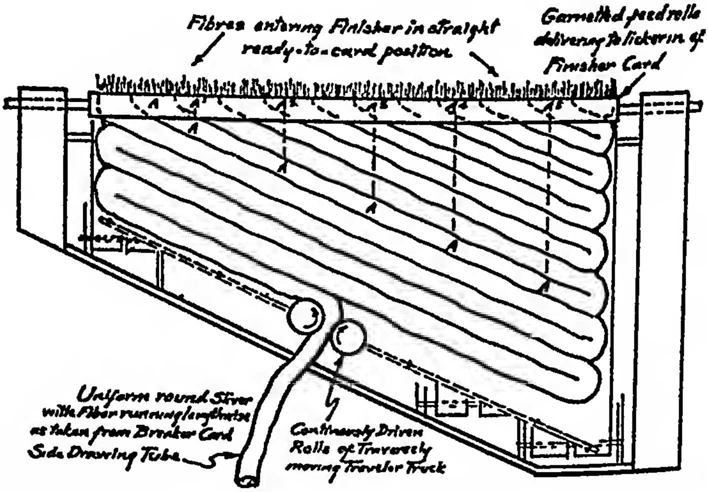


Fig 21. Top view of Harwood Apperly intermediate card feeder, showing sliver lay.

Between the first breaker card and the intermediate, or between the intermediate and the finisher card, a Peralta roller mechanism has been widely introduced that consists primarily of two heavy metal rollers through which the card web is passed The object of these rollers, as shown in Fig 22, is to crush any hard thready stock, burs, or shives present in the blend The presence of these substances in the blend will often interfere with the proper drafting and spinning of fine woolen yarns It is claimed that the Peralta rollers reduce the foregoing impurities by crushing them and carding them out The device consists of two 12-inch diameter rollers, A and B, made of chilled cast iron with a very hard polished surface (400-500 Brinell) The web of carded sliver is doffed from the first breaker card (scribbler) or the intermediate and passed between the rollers and subjected to a great pressure, consisting of the weight of the top

roller (1,776 pounds) and any extra pressure required, by means of a spring *D* and a handwheel *C* Pressures from 0 to 10,000 pounds can thus be created as needed. After passing through the rollers, the web is carried forward by a lattice apron or the Scotch feeder for the next card

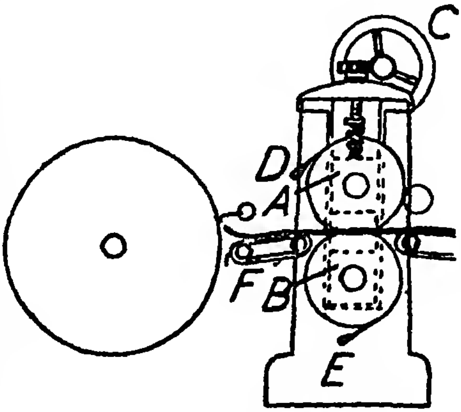


Fig 22 Peralta roller device

The advantages of this device are that: (1) extra carding is unnecessary, (2) the cost of blending can be reduced by using stock that has vegetable matter in it, (3) the same blend can be spun to finer counts, (4) no extra labor cost is involved, (5) less breakage occurs in spinning, (6) greater uniformity and strength of final yarn is possible; and (7) there is less burling to do in piece-goods

Second Breaker or Intermediate Card

The second breaker, often called the intermediate card in a three-card woolen system, is very similar to the first breaker, except that it has no bur cylinders These are replaced by a licker-in covered with coarse wire clothing, because the first breaker has done most of the rough work on the stock and removed burs to a large extent The coarse and heavy breast works found in the first breaker is also dispensed with for the same reason The licker-in is not only smaller but is provided with a licker-in fancy that serves to raise the stock and to effect its removal to the tumbler, which transfers it to the main cylinder (See Fig 14, showing complete layout of a three-card woolen set or system)

The wire with which the main cylinder, doffer, workers, and strippers, etc , are covered is finer and the card settings are closer in order to increase the amount of carding on this card In modern mills the intermediate or second breaker is directly connected with the finisher card by means of an angle stripper, eliminating the use of an intermediary-feed system The feed rollers of the second breaker are diamond-point wire instead of metallic feed roller wire

Where only a two-card system is used (a not too common practice in the United States) the intermediate card, of course, is eliminated and the sliver of carded stock is fed immediately to the finisher card

The Finisher Card

As the name implies, this is the last card in the three-card woolen system or set In all respects the finisher card is exactly the same as the intermediate, except that it is required that the finisher deliver the product in roving or, more commonly, "roping" form, ready for spinning Hence, added to the end of the card is a condenser that performs this function The card has the same general dimensions of all parts except that the wire with which the rollers are covered are still finer, depending on the stock being run. In the illustration of a whole set (Fig 14), the finisher has the same size doffer and one only Older existing machinery in many American mills still has the double-ring doffer, employed with the condenser Today these have been largely discarded and machinery builders offer the four-bank single apron or four-bank double-apron tape condensers, because they eliminate differences between top and bottom rollers and give a more uniform roping and yarn as well as an increase in card production of 20 to 80 per cent with less waste The tape condenser is now considered a necessity where automatic looms are used

Many types of condensers have been used in the United States and they may be listed in the following order:

1 Ring doffer system and condenser
2 Tube condenser
3 Roll condenser
4 Rub apron condenser
5 Combination roll and apron condenser.
6 Bollette condenser
7. Tape condenser

(See Chapter 1 for a history of the condenser and the part the United States played in its development)

The condenser is a vital and important part of the finisher card and, while more or less all of the types listed have been used from time to time, differences of opinion are prevalent as to their value on certain woolen stocks The four-bank single and double tape or apron condenser will be described here It is the only tape condenser which is offered by American machinery builders today although one concern still offers four-bank single, double triple or quadruple rub tape condensers; two-bank double or triple rub ring

doffer condensers; or single and multiple coilers However, it is admitted that tape condensers of four-bank construction is standard practice today on American woolen cards It is the preferred system for use in condensing woolen-carded-stock Tape condensers were first introduced in 1888 and can handle all woolen mill work, including the raw wool, substitutes and mixtures

Tape Condensers

The tape condenser (Fig 23) is stationed in front of the last doffer on the finisher card and is a separate unit by itself The tape condenser is built in 48-, 60-, and 72-inch widths, taking off from 60

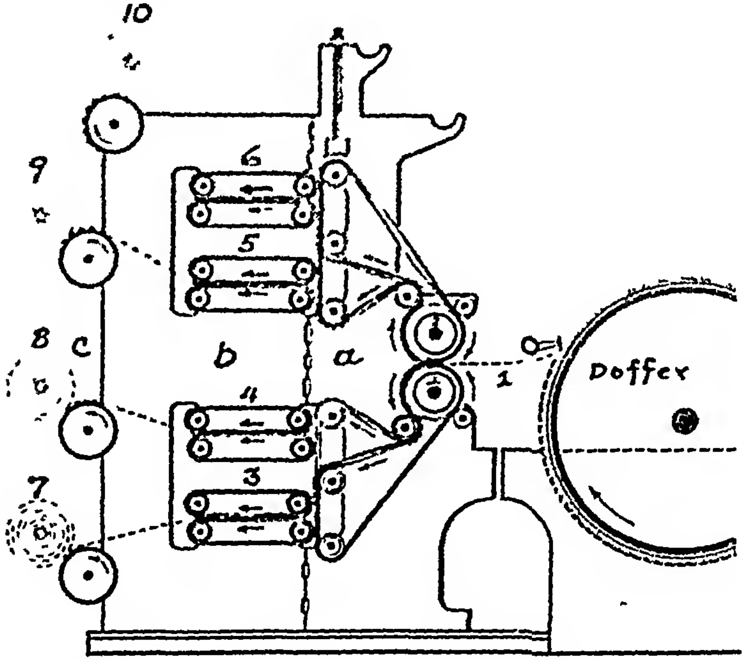


Fig 23 Principle of four-bank, single-apron, tape condenser

to 200 ends of roping, depending on the character of the stock and the size of yarn to be made It consists of three essential parts

1 The dividing of the card web by tapes
2. The rubbing or condensing of the ropings
3. The winding or spooling of the ropings

The web 1 (Fig 23) as it comes from the finisher doffer at full

width is passed through a pair of take-in rollers *2*, which are grooved and in which run endless leather tapes that divide the whole card web *1* into as many ribbons as the winder is equipped to handle. These wool ribbons are passed in groups of forty or forty-eight to the rub aprons *3*, *4*, *5*, and *6*, which operate in pairs. They are guided between the top and bottom aprons and receive there a slight sideward rub or roll as they pass through them, under some compression, emerging from the aprons to be guided or threaded to the roping spools *7*, *8*, *9*, and *10*, respectively. There they are wound on wooden-head, wooden-core jack spools or, if intended for dyeing, on a perforated core made of Monel metal with heads. In Fig. 23 the web and ropings are easily traced by dotted lines and there should be no difficulty in following their respective courses to each spool.

The previous description demonstrates the principle of the four bank, single-apron, tape condenser in its most modern construction, which has one tape for two ends. Compression rollers prevent the tapes from jumping out of their grooves in the divider rollers. When a tape breaks, the loose ends will not interfere with other tapes, will not force the compression roller away from the divider roller or allow other tapes to jump out of their grooves and be damaged. It simply runs on the floor without interfering. Provisions are generally made for speed changes in rub aprons, which have a forward motion as well as a quick to and fro side motion or vibration produced by eccentrics on the side of the frame. Positive drive of the finger rods or guides which direct the rolled ropings onto their respective spools, serves to give a well and solidly wound spool, ready for the mule. One of the latest improvements is the patented internal spool drum drive, the elimination of hubs and projections, and an improved waste end winding arrangement.

In the past it was not an easy matter to change the number of roping ends delivered by a tape condenser. A new patented arrangement provides the addition of two guiding rollers for tapes to reduce the number by one-half and double their size. Therefore, changing from fine to coarse yarns is now a simple matter. When producing one-half the former number of ropings, two ribbons carried by two tapes are doubled together and condensed into a single roping. As two tapes deliver their ribbons to form one roping, means had to be provided to guide the runs of the tapes into close proximity and this is the purpose of the new guide rollers.

The spool drum speed must be accurately adjusted to the delivery of the roping, and for that reason instant and fine adjustments car

be made by means of an expansion drum pulley while the machine is running If this were not possible, the tension between aprons and roping spools would cause stretching or lagging of the roping

The winding arrangement as shown can be done differently, if

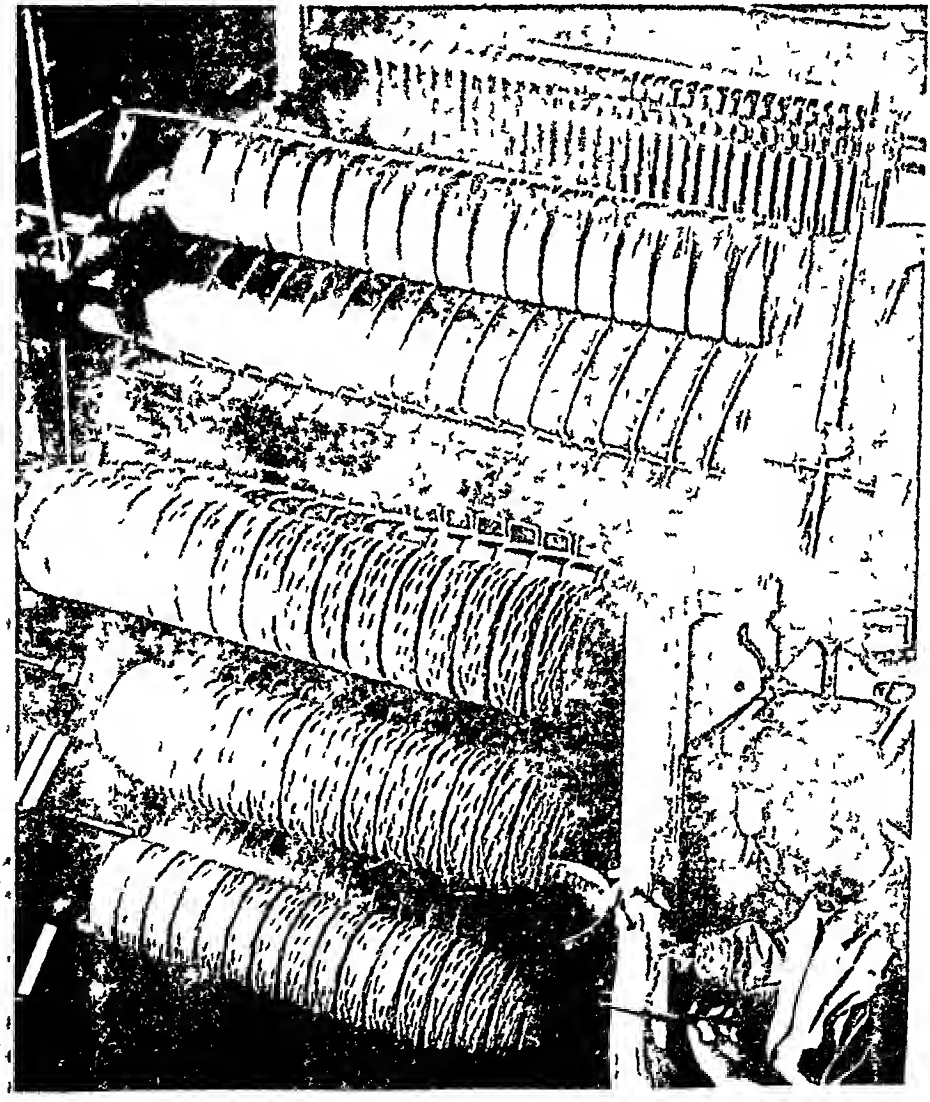


Fig 24 Carpet roving condenser and testing of roving weight
Courtesy Bigelow-Sanford Carpet Co

mill conditions demand by halving the four banks, each bank to carry two smaller spools, or by providing a special winding frame to give a special wind, or by providing only six spools Also, detached winders are made that can be transferred from one machine to another, if required, or can be used where the width of the spools is different from the width of the card, etc.

The 60-inch, four-bank, single-apron condenser requires about 2 hp to operate, whereas 3 hp are required for the four-bank double-apron condenser. The floor space of such condensers vary with the manufacturer but usually they occupy from 8 feet 3 inches to 9 feet 7 inches, single and double apron, respectively. The speed of the eccentrics is generally not over 300 r.p.m.

Condenser tapes and rub aprons are made of the finest leather and can be smooth, perforated, grooved, or with diamond-cut finish depending on the stock that is being worked A good tape must be square and not vary in width, since a variation will cause web ribbons of different or varying widths, hence a roving of different weight. The flesh side of the tape must be as smooth as the hair side. Each type should have the same grade of leather and be perfectly pieced. Thickness of the leather is of paramount importance, because the tension applied will cause a different stretch in the different tapes The leather must be firm and sizing must be resorted to make it firm. All of this goes to show that the condenser is a delicate and important part of the finisher card, which if not properly and expertly built, adjusted, or kept in repair, can cause much delay or unsatisfactory roping and, finally, really bad yarn.

Card Setting

The setting of a card is done by the foreman, the second hand, or the boss carder and involves the adjustment of all workers, strippers, fancy, dickeys, and doffers, etc., to the main cylinder and to each other, so that carding of the stock is thoroughly and effectively accomplished. Such adjustments, of course, are dependent on the following factors:

1. The length of the stock.
2. The condition of the stock.
3. The type or quality of stock.
4. The kind and nature of the card clothing.
5. The condition of the card clothing.
6 The relative speeds of the parts adjusted
7. The number of machines in the woolen set.

For instance, if the rollers are set too open or far away, the stock will not be properly carded or opened out If the rollers are set too close, the wool fibers will be broken or cut and the value or spinning property of the stock reduced Furthermore, settings on the first breaker are generally more open than on the second or intermediate card and still closer on the finisher card than on the two previous cards The boss carder is entrusted with all these details and has to keep constant vigilance to see that all cards are kept in perfect working condition at all times It is an art of great delicacy and requires a good gauge, a trained ear and eye

Card Stripping

According to the condition, i e, openness of the stock and cleanliness of the stock (freedom from dirt, dust, shives, grease, etc), it becomes necessary from time to time to clean or strip these wastes from the card clothing When stock is fine and contains little extraneous matter it may run satisfactorily for one week, however, if the stock is coarse and has much extraneous matter present it may have to be stripped every day. Everything else being equal the first breaker requires more frequent stripping than the second breaker and the latter requires more stripping than the finisher In some mills the first breaker is stripped every day, whereas in other mills it may be stripped every other day The intermediate may be stripped every second day and the finisher may run a whole week before stripping The factor that is taken into consideration here quite often is that the whole set is out of operation when any one of the three is stripped Some carders keep the intermediate and finisher going with spare or extra laps or with extra balls of sliver from adjacent cards To avoid this tie-up of cards some carders clean the main cylinder and doffer one day and clean the whole card the next day When this plan is adopted, it is well not to clean two cards of a single set all through at the same time in order to avoid making a large number of light rovings. Other mills have a stripping crew of two, four, or six men who strip all three cards at one time, probably the best plan, although the alternate plan is good and saves time. No hard and fast rule can be given and one must be guided by circumstances and local conditions

Reclothing of Cards

The reclothing of cylinders, workers, and strippers becomes neces-

sary when the wire becomes so short, owing to grinding, that it no longer serves its purpose, or because it has been damaged by fire or dented beyond repair In such cases the wire clothing is removed completely and renewed In case of a cylinder, this job is done directly on the machine, and without separating the cards This is a very delicate and precarious operation that must be handled by an experienced carder or foreman After the old card clothing has been completely removed, the cylinder is carefully inspected and smoothed down. All noil holes should have new wooden pegs inserted in them so that the new clothing can be tacked down several times, especially at the beginning and end of the job The mechanic begins at the left-hand side of the cylinder, tapers the clothing strip so that it goes on at an acute angle, and tacks it down twice A tension regulator for the card clothing strip is necessary so that it can be wound spirally on the cylinder This tension regulator maintains a uniform tension on the card clothing and has an indicator in clear view, which shows the tension to the operator at all times A special motor it attached to the cylinder which is reversible The clothing must be put on tightly, but not too tight Each spiral must be closed up against the previous one so no open space between spirals occurs This is continued until the card surface is completely covered At the other end of the cylinder, the final strip is again tapered off with a knife and fastened down with tacks The cylinder is then ground down to a perfectly smooth wire surface and leveled

Card Grinding

When card clothing has been in use for some time, particularly on coarse and poorly opened or matted stocks, it becomes necessary to sharpen or grind the wire points, which become exceedingly dull This applies in particular to main cylinders, workers, and strippers as well as to doffers At what point card clothing requires grinding is determined by the boss carder or, in some mills, by the second hand Generally, every three or four months card clothing is sharpened, although good card clothing today will run for six to eight months It depends a great deal on the quality of the clothing New card clothing must be sharpened and evened out after it has been put on the rollers

The grinding of card clothing, irrespective of whether it is sheet or filleting, has the following objectives:

1 To *true* the wire on the rollers, so that each wire point will be equally distant from the center.

2. To keep the points *sharp* so that they will catch the wool fibers
3 To keep the points *smooth* so that the wool fibers may be easily removed from them

New card clothing, irrespective of its price or quality, must be properly ground and evened out after placing it in position, this operation really determines its life and efficiency Many carders spoil card clothing by grinding it too often and too severely When grinding card wire two different kinds of points are obtained, depending on the procedure in grinding, namely, the *chisel point* and the *needle point* The chisel, diamond, or tool point is obtained when a stationary emery roll grinder is used It grinds the point down to a flat or chisel edge In practice this is not very satisfactory, because when a piece of metal is filed down or ground squarely across the grain, a hook or bur point may easily develop, to make a bad wire point and then the whole roller has to be reground

This cannot happen when a traverse grinder roll is used, because it grinds the tooth on each side as well as on the top, owing to the traverse back and forth over the whole roll This produces a needle

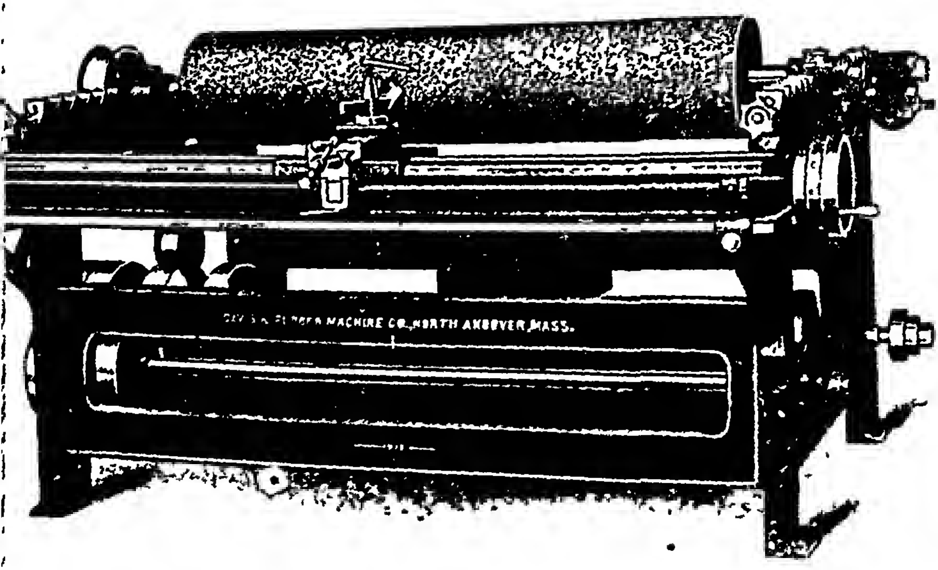


Fig 25 New Century floor grinder with 10-inch emery roller
Courtesy Davis & Furber Machine Co

point, which does not mean that it is pointed like a needle nor nearly as sharp. The term simply serves to distinguish it from the flat or chisel point

Fig 26 High-speed traverse grinder. *Courtesy Davis & Furber Machine Co.*

Roping and Production Details

The roping To secure the best production the roping should be round and compact, with the fibers evenly and closely laid and come uniformly on all spools Such roping must be reeled and tested regularly every day and, if cards are stripped or ground, two hours after starting up again In order to be spun satisfactorily, roping must have a definite number of yards per pound, not only on one spool, but on all spools and continuously It is one of the duties of the carder or second hand to check the roping regularly and exactly, especially when changing a set of cards over from one weight of roping to another.

The sizing of the roving from a finisher card is done by weighing a given quantity, usually 5 or 10 yards, on a grain scale. Some people take 40 ends 1 yard long = 40 yards, or 48 ends 1 yard long = 48 yards, and weigh the same in grains. Careful procedure is essential here. Usually top and bottom spools are used for two separate tests They are then figured over into cuts or runs, depending on the system most commonly used in each mill, which differs with the locality of the plant For instance, if it is desired to make a four-run yarn and there are 48 ends, the side drawing from the first breaker should weigh 200 to 220 grains per yard.

When it is desired to change the weight of the roping, it is best to secure the proper results by means of the feeder adjustments and not by means of the draft gears, which generally results in bad work. Changing the weight should be done by changing the gear on the

feed rollers which drive the dumping arrangement and feeder apron

Since the roving goes directly to the mule for spinning, no opportunity for correction of the uniformity or weight of the roping is available Uneven roving is the bane of the boss carder's existence

Static electricity, which is very likely with a dry stock or dry atmosphere, should be avoided as much as possible in a woolen card room. The place where it is most serious is the condenser on the finisher, due to the friction which the stock encounters there The only remedy is to keep the stock damp, to provide humidifiers, or to use neutralizers (Fig 27)

Production and speed of cards The greater the width of the cards and the coarser or thicker the roping being made, the greater is the

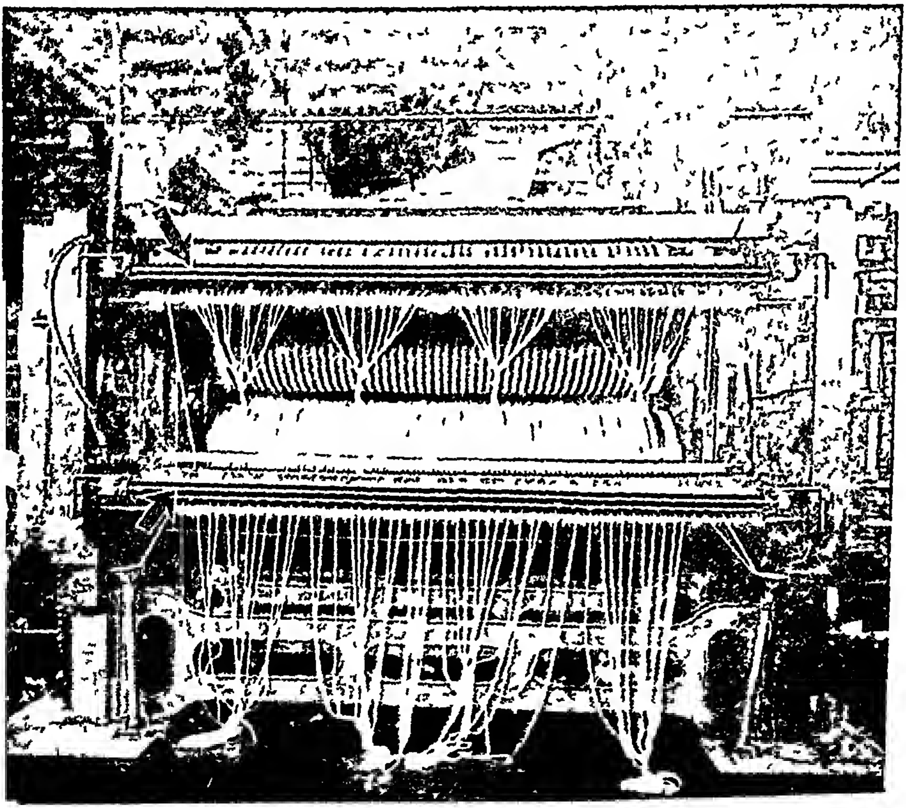


Fig 27 Electric neutralizer bars installed on a finisher card
Courtesy Chapman Electric Neutralizer Co

production. A fair average production for a set of cards 48 inches wide may be estimated at from 400 to 450 pounds of roving per day on two-run yarns The production may be as high as 600 to 700 pounds per day (single shift).

The speed of a woolen card is stated in terms of the main cylinder rotation A 48- by 48-inch card should not be run faster than 90 r p m, a 60- by 60-inch iron, three-card "set" should be run not faster than 72 r p m, which are two speeds commonly adhered to.

Chapter 11

SPINNING WOOLEN YARNS

THE art of spinning wool dates back to prehistoric times, when necessity forced attention to the making of threads or tissues of different character, however crude, to fasten skins together and provide wearing apparel to keep the body warm For many centuries the matter remained static until someone thought of the idea of the distaff and spindle, which was used by the Egyptians, Babylonians and other ancient races. The spinning wheel, which was the next step in the art of spinning, is supposed to have originated in India

The first record of the use of the spinning wheel in Europe was found in the beginning of the sixteenth century With this device, seven times as much yarn could be produced as before Machine spinning did not come about until the "jenny" was invented in England about 1762 (See Chapter I) In 1779 the first machine incorporating the jenny was invented in England, where the spindles were placed in a movable carriage, constituting the first approach to the modern mule. The next development was a very gradual one, and involved the application of power to this hand-operated device of about 20 spindles Shortly after the invention of the jenny came the "billy" Power spinning was not introduced into this country until about 1814, between the years of 1812 and 1826 the hand jack came into common use in woolen spinning which, at that time, had a capacity of about 200 spindles It continued to be used until after the Civil War

In 1868 and 1869, experiments were made with a view toward producing a self-operating jack in Worcester at the plant of Cleveland and Bassett, later Johnson & Co, which became Johnson & Bassett in 1870 The first Johnson & Bassett mule was built in 1871, the first self-acting woolen mule in America The Davis & Furber Machine Co claims to have built self-operating heads on hand jacks in 1870, and in 1874 began making self-acting mules Since then, woolen mules have been universally employed for woolen spinning in all parts of the woolen industry of America, and the modern mule has developed into the most ingenious piece of textile machinery in existence. In 1929 a census of manufacturers reported 2,303,207 woolen spindles in place in the United States, whereas in 1945 only 1,609,303 were reported, a reduction of 30 per cent in 16 years.

This, however, is not to be interpreted as a shrinkage in total capacity Actual production was greater than in 1929 because of more spindle hours of operation and a larger production per spindle According to the Bureau of Census, of the total number of 1,653,550 woolen spindles in place in 1943, 1,395,197 were mule and 258,353 were ring spindles

From 1912 on, attempts were made by the Whitin Machine Works in this country, and by Platt Brothers in England, to apply the principle of continuous ring spinning to woolen yarns These efforts to make woolen spinning a continuous operation eventually were successful While the mule is still the dominant factor in spinning woolen yarns to give softness and fullness, and is especially advantageous in handling very short and weak stocks, it does appear that ring spinners seem to have overcome the main objections to the mule i e, the small intermittent output, the large floor space required and the high labor costs.

Woolen Spinning

The wool stock, which has been carded and converted into a roving in the conventional manner described in Chap. 10, is now ready to be spun into yarn of the required *run* or *cut*. By run or cut are meant numbers designating the yarn size, based on length of yarn per given weight. (See woolen and worsted yarn calculations) Woolen spinning involves three principal operations, irrespective of whether the mule or the frame—or ring—spinner is used, namely,

1. Drafting, or final drawing out
2. Twisting, or insertion of twist
3. Winding-on, or packaging

Drafting, or drawing, concerns the last reduction or attenuation of the roping itself to that weight or thickness required in the final woolen yarn, for instance, two *run* or its equivalent, 10 2/3 *cut*. In the mule this is accomplished by a so-called *spindle* draft instead of a *roller* draft, as is done on the woolen ring spinner, or in worsted spinning.

The drafted roving is then twisted to give the yarn sufficient strength for it to be knitted or woven On the woolen mule this process is partly combined with drafting, but mainly accomplished by *spindle twisting* On the woolen ring frame the twisting is done by use of a ring and traveler, and is termed *ring twisting*.

Winding-on consists of putting the spun yarn into a form such as *cops* or *bobbins* suitable for succeeding weaving or knitting opera-

tions Large packages are the latest development in that line, particularly for carpet, felt and blanket yarns, where bobbins up to 15 inches in length and 3½ inches in diameter are employed

Since the mule or jack is the machine most commonly employed in spinning woolen yarns in the United States, it will be described first,

The self-acting mule The modern mule on which woolen yarns of all sizes and descriptions can be spun, is often termed the self-acting mule, because of its practically automatic operation Most people divide the whole machine into two main sections, i e , the *head stock* and the *carriage*. The former receives its power from the main shaft, and in it originate all the important motions of a mule This part of the mule is usually stationary. The carriage, however, is movable and bears the spindles that draft and spin the roving into yarn, and then wind it on the bobbins The carriage extends over the whole width of the machine, and is slowly moving in and out during the spinning procedure

General spinning procedure When the operation of spinning begins, the carriage X (Fig 1) is up close to the delivery rolls H-G-H As the rolls and drum L on which rests the jack-spool M start to deliver the roping, the carriage X moves out at practically the same speed as the roping is delivered When the spindle C reaches a certain point, which is determined by the nature of stock, the drum L and rolls H-G-H stop and the carriage X continues to move out 60-70 inches from the rolls The roping is thereby drawn out to about twice its

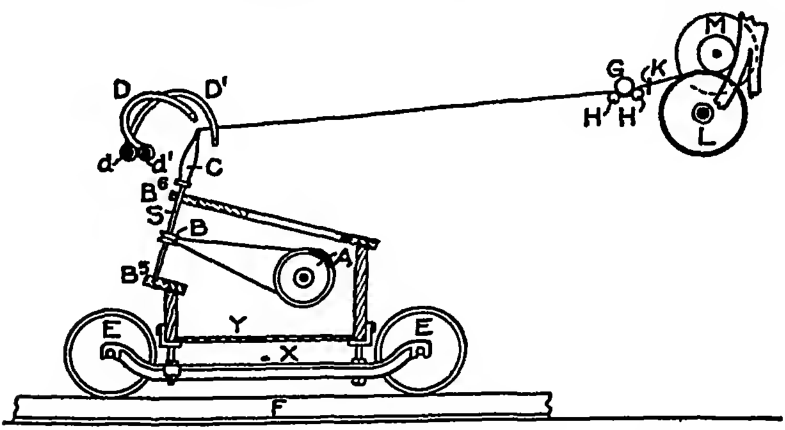


Fig 1 Sectional view of mule showing its main parts

original length, or its *spindle draft* During the above motion a certain amount of twist is put into the roving by the drum A connected with the spindle whorl B This is accomplished by the roving slipping over the spindle The spindle C, being placed at an angle, does not hold the yarn, but simply allows it to slip over the top of spindle as shown in Fig 1 One turn of twist, therefore, is put into roving for every revolution of the spindle C The combined drafting and twisting action of the mule gives its peculiar formation to the woolen yarn When the carriage X has reached the end of the draft it is stopped and, while in that position, required additional twist is quickly put into the yarn to give it greater strength At this point what is termed the accelerated speed motion is sometimes used After the twisting is completed, the spindle C reverses for a few turns This is called *backing off* The faller fingers D-D now begin to function, tensioning and guiding the yarn onto the bobbin C The carriage X then starts back toward the rolls H-G-H This is called the "draw-in-motion" At the same time the faller fingers are ascending and descending, guiding the yarn onto the bobbins When the carriage has returned to the rolls, the mule goes through the same motions again until the set of bobbins is filled with yarn.

The principal motions on a mule can be stated in sequence as follows for easier explanation:

1 Drawing-out motion
2 Draft and twist motion
3 Ease-up motion
4 Backing-off motion
5. Winding-on motion
6 Drawing-in or re-engaging motion

These are the essential motions in all mules, irrespective of their make The motions take place successively, overlapping somewhat, and will be described on the basis of the preceding diagram in as simple terms as possible At the outset it must be realized that it may be somewhat difficult to coordinate the movements of the various motions and their function at the different periods, because a certain portion of the mechanism may be performing one function, whereas, at another period of the spinning process, it may be performing a totally different one, both direction and velocity being changed The headstock is the source of practically all of the above motions which are transmitted to other parts by means of belts, bands, ropes and chains, as well as gears.

Drawing-out motion The first motion brought into play on the mule is the drawing-out motion, which is the outward travel of the spindle carriage from the beam or, if directly in front of the draw rolls, to a distance of about 40-60 inches from the starting point

When the mule starts out, the spool drum L, the bottom feed rolls H-H, the spindle C and carriage X begin moving (Fig 1) The roving is being delivered by the roping spool M at the same rate as the carriage, with its spindle, is moving away The roving, in its passage from the jack spool M, passes through a trumpet K and through two fixed, driven rollers H and H and top roller G (not driven), which rests on the other two and rotates with them by friction only.

As the carriage moves out, a slight amount of twist is inserted into the roving by the rotating spindle C, whose rotation is imparted to the spindle by a drum A connected with the spindle whorl B by bands, fallers D and D1 are out of action at this moment When the carriage has traveled a distance of 50 to 60 inches in a 74-inch draw[1], the jack spool M and the feed rolls H and H are stopped, but the carriage continues more slowly until the end of the 74- or 76-inch draw is completed During this portion of the draw, the roving is drafted (or *spindle* drawn as against *roller* drawn) out and the twisting or twist motion comes into play to impart the necessary amount of twist to the shaping woolen yarn

Twist motion Each revolution of the spindle C imparts one turn of twist to the yarn, accomplished by the slipping of the yarn over the smooth and round tip of the metallic spindle, for which purpose the spindle is inclined away from the vertical toward the feed rolls The tendency of the yarn already spun is to rise to the top of the spindle, where it slips over the end, putting in one turn for every *slip*.

The twisting motion goes into action as soon as the drawrolls stop the delivery of roving The required twist for the length of drawn roving, i e, 74-76 in, is now put in by increasing the speed of drum A so that the required twist has been inserted when the draw is complete.

Davis & Furber recommend the use of the following table in determining *holes* of twist, which are based on a 1-in whorl for ordinary work, and a 1¼-in or 1½-in for heavier work (cylinder pulley of 10-in diameter) Since the yarn shortens as it twists, the ends would snap off if there were not some method of easing-in or backing-off.

[1]Draws may vary from 66 to 76 in in length

TABLE 1

TABLE SHOWING TURNS OF TWIST PER INCH IN YARN FOR SINGLE AND ACCELERATED SPEED MULES 72" DRAFT 1" WHIRL

NUMBER OF HOLES OF TWIST →

DIAMETER OF RIM WHEEL →

Diam of Slow Speed Rim	Revs of Cylinder to 1 rev of Rim Shaft	4	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	Add for 1 Hole	Add for 2 Holes
11	1068	60	18	24	31	3.7	43	49	5.5	61	67	73	79	85	92	98	104	110	116	122	128	134	140	147	153	159	305	611
12	1165	67	20	2.7	33	40	47	53	60	6.7	7.3	8.0	8.7	93	100	107	113	120	127	133	140	147	153	16.0	167	173	334	667
13	1262	74	22	2.9	36	44	51	58	6.5	72	80	87	94	101	109	116	123	130	137	145	152	159	166	174	181	188	361	722
14	1359	81	24	31	39	47	55	63	70	78	86	94	101	109	117	125	133	140	148	156	164	172	179	187	195	203	389	778
15	1456	88	26	34	42	50	59	67	75	84	92	101	109	117	126	134	142	151	159	16.7	176	184	192	200	208	217	417	834
16	1553	95	27	36	45	54	63	72	81	90	98	107	116	125	134	143	152	161	170	178	187	196	205	214	223	234	445	889
17	165	102	28	39	48	57	67	76	8.6	95	105	114	124	133	143	152	161	171	180	189	199	209	218	227	237	246	473	945
18	1747	109	31	41	51	6.1	71	81	91	101	111	12.1	131	141	151	161	171	181	191	201	211	221	231	241	251	261	500	100
19	1844	116	33	43	54	64	7.5	8.5	96	107	117	12.8	138	149	16.0	170	181	191	202	212	223	233	244	254	265	275	528	1055
20	1942	123	35	46	56	68	79	90	101	112	123	13.5	14.6	157	168	179	190	201	212	223	235	246	257	268	279	290	556	111
21	2039	130	36	48	6.0	71	83	95	106	118	130	141	153	16.5	176	188	200	211	223	235	246	258	270	28.1	293	305	583	1166
22	2136	137	38	50	63	75	81	99	111	124	136	148	160	173	185	197	210	221	234	246	258	271	283	295	307	319	611	1222
23	2232	144	40	53	6.5	78	91	104	117	13.0	142	155	168	181	193	206	219	231	244	257	270	283	296	308	321	334	639	1277

Amount of twist. There is no set rule or standard twist for woolen yarns, but a warp yarn should have enough twist and be strong enough to knit or weave satisfactorily The turns per inch of woolen yarn vary according to the length and quality of the stocks, blends and conditions of roping Such yarns are usually tested by hand and comparison made on the basis of practical experience with troublesome yarn in the past The amount of oil or lubricant used has much to do with the amount of twist put into a woolen yarn If properly lubricated, the twist will travel more evenly through the yarn

Twist factors These factors are based on 100 per cent clothing wool, of 1 inch to 1½ inch lengths. The amount of twist is governed by the length of the fiber, i e., long wools and short noils In Table 2, the twist terms *soft, normal, medium hard* and *hard* are merely relative In fleece wools maximum strength is generally produced by a warp twist In the case of blends containing 50 per cent or more noils, the twist must be increased to give satisfactory running yarn, whereas the twist must be decreased in long wools, mohair and alpaca blends. Another factor influencing the amount of twist to be used is the desired hand and finish of the final fabric To produce a crepe, the

hard twist is used Table 2, showing the twist in woolen yarns, is to be used only as a guide and not to be construed as a standard The great variety of combinations of short and long stocks prevents standardization of the twist Table 3 shows the twist multipliers that can be used with various sizes or *runs*

TABLE 2 SINGLE YARN TWIST OF WOOLEN YARNS

(Twist in turns per inch)

	Degrees of Twist				
		Normal			
Yarn Number Run	*Soft*	*Filling*	*Warp*	*Medium Hard*	*Hard*
0 25	1 66	2 07	2 52	3 00	3 44
0 50	2 50	3 30	3 92	4 62	5 34
0 75	3 08	3 95	4 84	5 71	6 59
1 00	3 57	4 58	5 60	6 62	7 63
1 50	4 38	5 62	6 87	8 12	9 37
2 00	5 05	6 48	7 93	9 36	10 82
2 50	5 64	7 27	8 87	10 48	12 09
3 00	6 19	7 98	9 74	11 48	13 25
3 50	6 70	8 51	10 49	12 40	14 31
4 00	7 14	9 18	11 21	13 26	15 28
4 50	7 57	9 73	11 89	14 06	16 21
5 00	7 98	10 25	12 55	14 82	17 11
5 50	8 37	10 77	13 16	15 55	17 95
6 00	8 74	11 23	13 73	16 25	18 75
6 50	9 11	11 70	14 31	16 91	19 52
7 00	9 45	12 15	14 85	17 54	20 25
7 50	9 77	12 58	15 38	18 16	20 95
8 00	10 09	12 98	15 86	18 75	21 63
8 50	10 39	13 38	16 36	19 33	22 29
9 00	10 69	13 77	16 84	19 89	22 94

TABLE 3 TWIST FACTORS FOR WOOLEN YARNS

(Mule Spun)

Degrees of Twist	*Run System Factor*
Soft	3 57
Normal, filling	4 58
Normal, warp	5 60
Medium hard	6 62
Hard	7 63

Formula Turns per inch = Factor $\sqrt{\text{Run of yarn}}$

Back-off motion When the full length of the draw has been taken, and before the operation of winding the yarn onto the bobbin can begin, the small amount of yarn between the top of the spindle and the yarn already on the bobbin must be unwound To do this the spindle will revolve in the *opposite* direction for a few turns. This motion is known as the *back-off* The tension faller D1 and the winding faller D operate as the back-off motion is brought into play The inside winding fallers guide the yarn onto the bobbins, and the tension faller tensions the slack yarn Since the operation of twisting shortens the length of the thread, an ease-up motion is necessary It allows the carriage to travel more slowly while the twist is being put in.

Winding-on motion The winding of the yarn is done while the carriage is being drawn-in toward the rolls, by means of a quadrant mechanism The carriage pulls against the quadrant and unwinds the quadrant chain This chain is wound onto a drum on the winding shaft, on which a large winding gear is located. This gear meshes

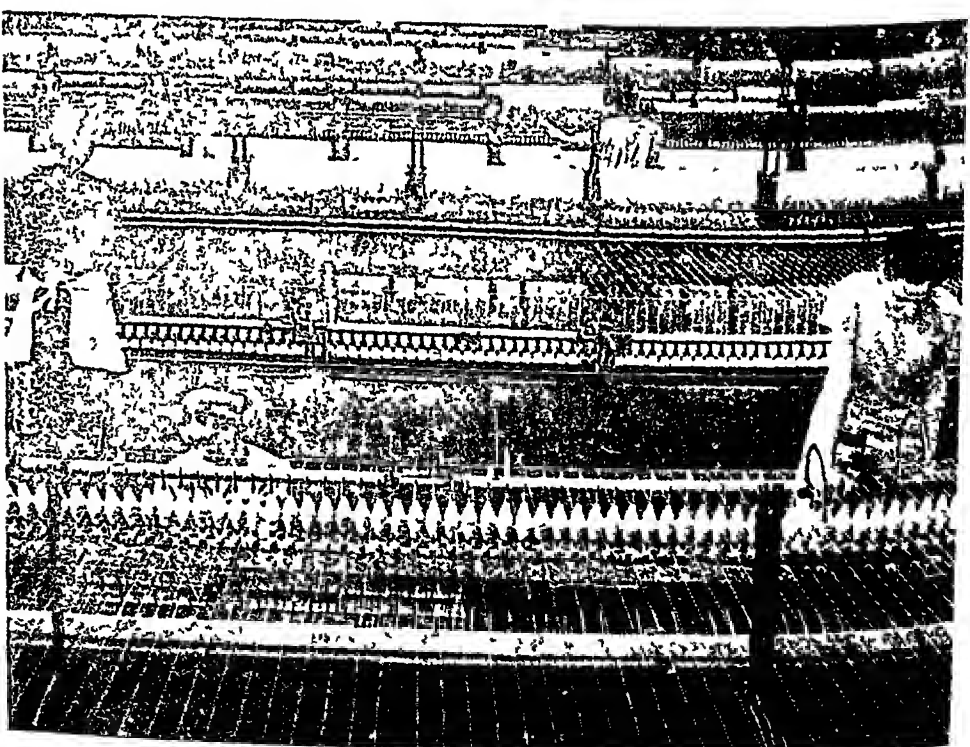


Fig 2 Interior of a woolen spinning room *Forstmann Woolen Co*

into the cylinder gear on a center cylinder shaft, which functions with winding clutches to operate the driving drums The spindle bands pass around cylinders and whorls on the spindles and, as the cylinders turn, impart a rotation to the spindles

The object of the builder motion is to build the bobbin shape while the carriage returns It works with the winding fallers to build a bobbin of definite shape and size As the carriage is drawn in, the quadrant mechanism imparts the necessary movement of the spindles, the builder motion guides the yarn onto the bobbin to produce a bobbin of the required size and shape The yarn is guided onto the bobbin by the winding faller, the counter or tension faller simply keeping the yarn taut to prevent kinks in the yarn The hardness of the yarn on the bobbin may be regulated by weights on the counter faller

Drawing-in motion This pertains to the movements necessary to return the carriage to its original position in front of the draw rolls and is done by means of ropes, drawing-in scrolls and clutches There are three scrolls on the mule Two of the scrolls wind up the draw-in ropes, and draw in the carriage The third is a check scroll, which checks or steadies the action of the other scrolls

This is the complete cycle of operation in mule spinning which repeats itself constantly Only 72 to 76 inches of yarn are spun at one time, which is characteristic of mule spinning

General mechanical details Self-acting mules require 5 to 15 horsepower to operate and occupy a floor space of 40 to 100 feet in length and 11 to 12½ feet in width Mules are furnished and classified according to the number of spindles employed, varying from 200 to 450, common sizes being 200, 220, 260, 320, 360 and 400. The weight of the mule is in the neighborhood of 7-12,000 pounds; the height usually does not exceed three to four feet Spindle speeds vary from 3000 to 5600 rpm The gauge of a mule is the distance between the centers of two consecutive spindles Ordinary woolen mules have gauges of 2 to 3¼ inches The driving pulleys of a pair of mules are 14, 16, 18 and 20 inches in diameter and back shafts are run, usually, at 330 to 360, and never less than 320 rpm For carpet mules the speeds are slower and the gauges wider

Production of a mule. If it runs continuously, the production of a mule can be calculated in pounds per each spindle per 10 hours as follows

$$\text{Weight in pounds} = \frac{45}{\text{Run no x seconds/draw}}$$

For example, if 3-run yarn was spun on a mule making four draws per minute, or one complete draw in 15 seconds, on a 200-spindle mule with no stoppage, the production per 10 hours would be

$$\frac{45}{3 \times 15} \times 200 = 200 \text{ lbs of 3-run yarn/10 hrs}$$

Mule stoppages are numerous and vary from 5 to 15 per cent for piecing and doffing to give an operating efficiency of 85 to 95 per cent Waste yarn amounts to 2 to 3 per cent Ten per cent more filling than warp yarn can be produced normally on a mule Extra spindles gradually decrease the mule's efficiency. Davis and Furber has published a production tab'e for single speed mules, which is of some help in calculating production of mules The table is made for their twist pin gear with 100 teeth, 50 holes driven by 15 and 30 tooth bevels

TABLE 4 PRODUCTION OF A MULE

(Single Speed)

Holes of twist	*Lbs per spindle in 10 hrs for 1 r p m of back shaft 1 run*	*Holes of twist (Continued)*	*Lbs per sp etc (Continued)*	*Holes of twist (Continued)*	*Lbs per sp etc. (Continued)*
8	01445	22	00696	36	00458
9	01341	23	.00671	37	00446
10	01252	24	00647	38	00436
11	01174	25	00626	39	00426
12	01104	26	00606	40	00417
13	01043	27	00586	41	00408
14	00988	28	00569	42	00399
15	00939	29	00552	43	00391
16	00895	30	00536	44	00382
17	00854	31	00521	45	00375
18	00817	32	00507	46	00368
19	00783	33	00494	47	00360
20	00751	34	00481	48	00354
21	00722	35	00469	49	00347
				50	00341

Instructions for use of table Take the figure in the table opposite the holes of twist being used Multiply it by the speed of the back shaft and by the number of spindles on mule This will give the number of pounds of one-run work that would be spun on a mule in 10 hours, if it ran continuously If on four-run work, divide by four to get proper weight, etc (If measured by grains, use the yarn tab'e and change to runs) This table is made for a twist pin gear with 100 teeth, 50 holes, driven by 15 and 30-tooth bevels. If the old style

bevels are in use with mitre gears, both 23-teeth, divide the result by 2

For example, suppose a 200 spindle mule runs at 340 revolutions per minute of the back shaft with 24 holes of twist on three run work, the equation would be

$$\frac{200 \times 340 \times 006475}{3} = 147 \text{ lbs in 10 hours, provided the mule}$$

never stopped If then, by actual weight, one were getting 100 pounds in 10 hours, one would know that the mule was running 100/147 or 68 per cent of the time, and that it was being stopped for piecing and doffing about 32 per cent of the time

Continuous Wool Spinning by the Frame Method

The spinning of woolen yarns in a continuous manner by the frame method as contrasted to the intermittent delivery of yarn by the jack or mule, is a recent development in this country The Whitin Machine Works has been the pioneer in this field, whereas some experimental work has been done in England Davis & Furber has also gone into this business The wool spinning frame is being rapidly accepted by the woolen trade because, with its use, it has been able to meet increasingly competitive conditions It is claimed to suit all grades of wool, mixtures of wool, cotton and rayon, coarse carpet yarns and knitting yarns, as well as high grade tweed yarns

The chief advantages of the ring spinning frame on woolen yarns are the following

1 Production between 2 to 4½ times greater
2 Floor space for a given production reduced by 60 per cent
3 Cheaper labor costs in many cases
4 Larger packages, less time lost in doffing
5 Yarn quality equal to and more elastic than that of the mule
6 Warp yarns with fewer knots
7 Reduced costs in succeeding operations

The above points are no longer in dispute, and have been demonstrated under actual mill conditions There were about 258,353 ring or frame spindles in place in the United States in 1943

Principle of frame spinning On a wool spinning frame, the drafting is done between two pairs of rolls, with a device known as a twister head located between each pair The twister head on the Whitin frame is designed with two tips at the top of a tube and a jaw on the base of the tube, which closes through centrifugal force Immediately in back of the twister head a steel rod is fastened called a deflector

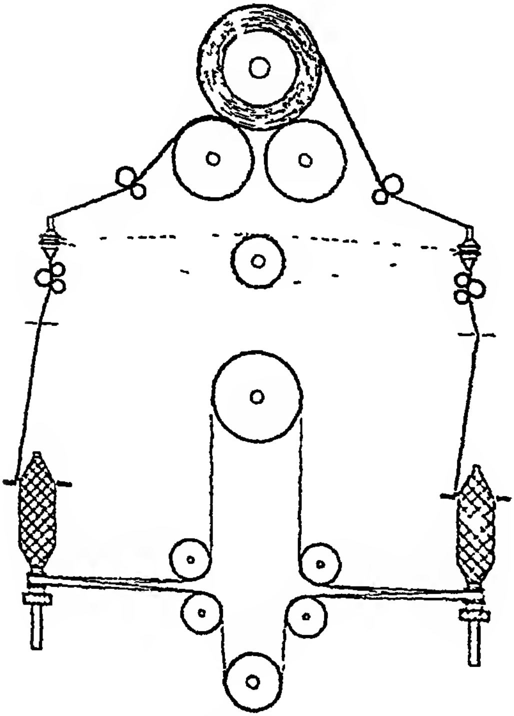


Fig 3 Diagram of Whitin Model E wool spinning frame, showing counter-balanced rails and spool drum drive.

The roving spools from the card condenser are held either between two parallel lines of drums, in which case every other end of roving is carried to alternate sides of the frame, or on two parallel lines of drums, when all of the roving on the spool is carried to a single side of the frame. These drums, by rotary action, pass the roving to a pair of delivery rolls At that point, the roving is drawn over the deflector rod, through a twister tube, to the drawing rolls (Fig 3)

The bottom, or drawing rolls, are revolved at a speed greater than the back delivery rolls, and this elongates, or *drafts* the roving. The twister-tube-jaw holds the yarn so that, as the tube revolves, a certain amount of "false" twist is imparted to the yarn during the drafting operation, and the two small tips on top of the tube agitate the yarn in the same manner that the spindle tip acts on a mule spindle, to give the same lofty, full yarn The amount of agitation imparted to the yarn is determined by the position of the deflector rod If a lean worsted-type yarn is desired, the deflector rod is raised, allowing very little action by the twister-tube-tips on the yarn, so that the fiber ends are not thrown to the outside, and the desired type of yarn results This operation is continuous

When the yarn reaches the nip of the bottom pair of rollers, the false twist which has been imparted is all removed, and the actual twisting operation takes place between the bottom nip of the drawing rolls and the spindle.

The essential features of the Whitin wool spinning frame are the adoption of the mule principle combined with the advantages of greatly increased production, reduction in floor space occupied, and the low labor costs entailed in the ring system of spinning.

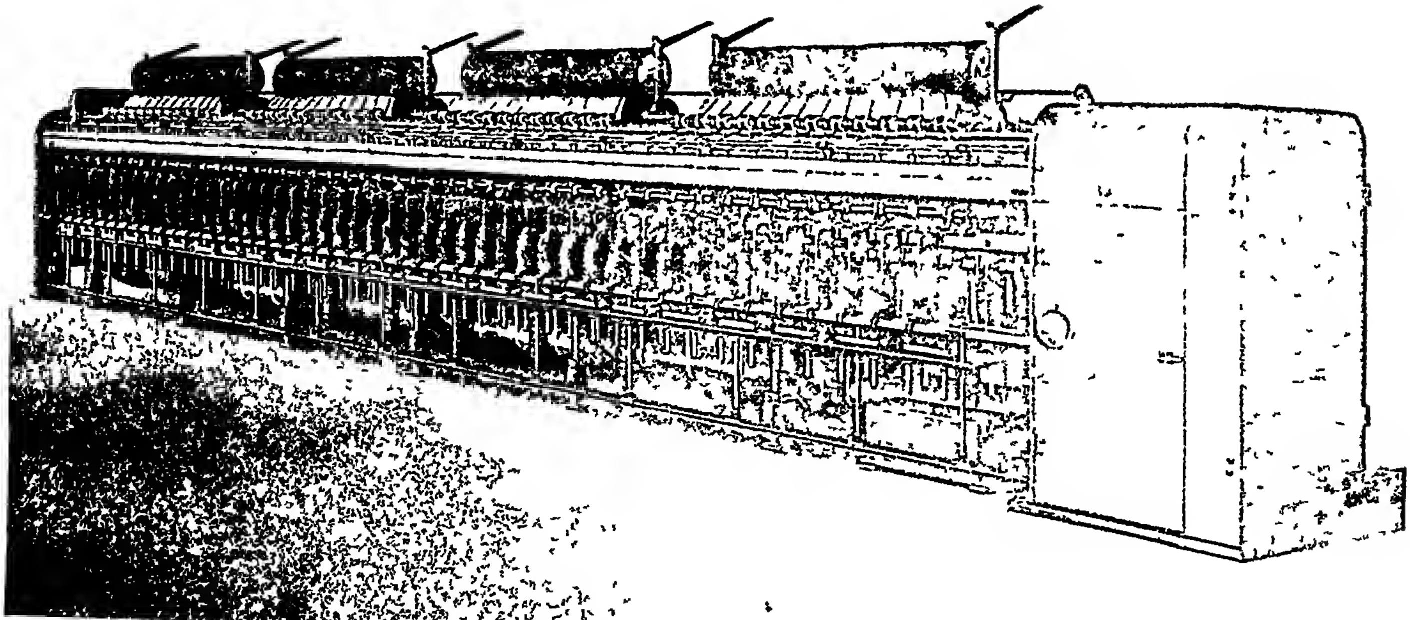
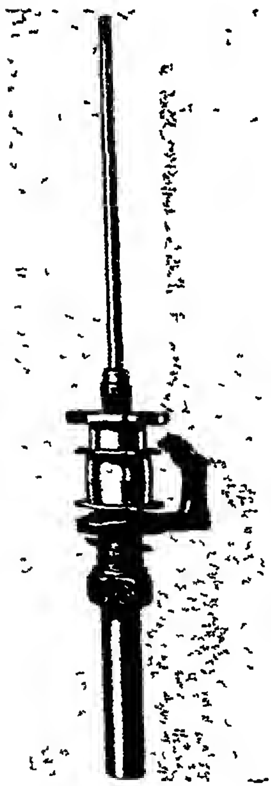


Fig 4 Large package woolen ring spinner *Courtesy Whitin Machine Works*

If roving delivered to a mule or to a spinning frame is slightly uneven or *twitty*, the lean spots will contain an excessive amount of twist On both the mule and the frame, this occurs in the drafting operation; on the mule this excessive twist remains in the lean place, whereas, on the spinning frame the drafting twist, because it is a false twist, is removed as it reaches the nip of the rollers, and the real twist is inserted after the roving has been levelled This is the chief reason why frame spun yarn is evener than mule spun yarn and, therefore, stronger. The wool spinning frame spins yarn from roving made as heavy, or heavier than that used on the mule. In other words, the frame will never draft less and, in most cases, will draft more than is possible on the mule.

The latest frame is streamline with enclosed head ends, one shot lubrication, motor drive, reverse twist mechanism, traversing device, all-metallic thread board, automatic deckboard wiper, anti-friction bearings, and an improved high speed spindle, shown in Fig. 4.



Mechanical details The frame is of heavy, cast iron construction The rolls are made of special, high-carbon crucible steel, case hardened, with bearings and flutes, ground to size, the roll flutes filed and polished to insure smoothness The machine handles either one or two rows of jack-spools In this machine, the ring rail is stationary and the bobbin is built by the lift of the spindles This is claimed to give absolutely even tension, since the same distance exists at all times between the drawing rolls and the traveler. The deflector rod is found immediately above and in back of the twister heads, and varies the amount of agitation produced by the twister tube pins as required. Silent chain drives are used in the driven and driving chains An all-steel, metallic thread-board and patented, individual lappets and porcelain thread guides which can all be lifted manually by one lifter, are features of this machine The spindles are tape-driven gravity spindles, simple in construction, steady in operation and durable They do not throw oil and consume a minimum of power. The improved Whitin-Magrath bobbin clutch is used. (Fig. 5.)

Fig 5 Whitin improved spindle with clutch.

Both horizontal or flange rings, as well as self-oiling vertical rings, are employed, the latter being preferred in the United States This is due to several advantages offered by the latter, including a more even tension on the yarn with less end breakage, a greater elasticity in the spun yarn, marked reduction in flyings, and an increase in the length of service obtained from travelers The vertical ring is usually lubricated two or three times each day by wiping the inner wall with a small amount of compounded lubricant Improved ring travelers are available which are made from beryllium copper (2 per cent Be, 98 per cent Cu) and have six times the life span of the regular high carbon steel travelers

While the plain vertical ring has been found generally satisfactory, for high speed spinning a special vertical ring was developed, through the use of which the traveler is *uniformly* and *automatically* lubricated at all times, without interruption of operation (Fig 6) A reservoir or receptacle located outside of the ring is filled with oil, which is drawn by capillary attraction along a wick, passing through two small holes drilled in the outside wall of the ring and connected with the inner side by a short recess A slow, steady flow of oil is delivered

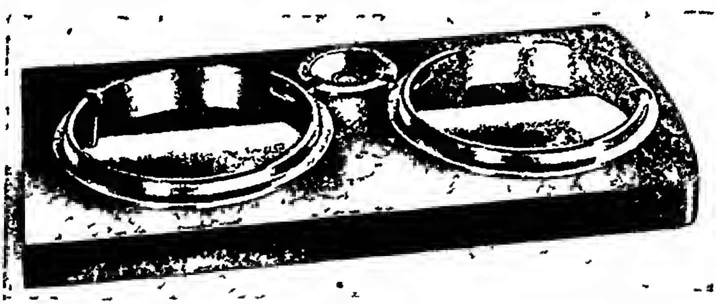


Fig 6 Auto-lubricated vertical rings with oil reservoir (*Whitin*)

to the wick, and during the spinning operation, a film of oil from the wick is transferred to the wall of the ring by the action of the traveler so that there is positive lubrication at all points Anything that interferes with this capillary action such as dust, particles of metal, an excessive temperature, or anything that causes the wick to carbonize, stops the flow of the lubricant to the wall of the ring Rings should be wiped out at every doff to remove abrasive material Wicks should be inspected weekly and rings re-wicked semi-annually A spare set of wicks and rings should always be at hand

On both the plain vertical and the automatically lubricated vertical rings, certain conditions call for different *types of travelers*. For example, when a burry wool is used in the blend, or if shives or chaff are present, a larger traveler head is desirable to allow such vegetable matter to pass unhindered through the traveler.

The twister head This patented device, also known as the false-twist-tube, is an important part of the wool spinning frame (Fig. 7) It consists of a mouth piece, bowl-shaped with four pegs projecting from the inside face into the path of the wool The slubbing is fed into this tube from the feed rolls, and is agitated and partially held by the notches or two small projections until it slips away from them as the tube is rotated The jerks exerted by these projections are intended to have a leveling effect on the thick places that may be in the yarn The lower end of the tube is tapered almost to a point, and as the roping emerges, it is grasped by the spring jaws It passes through front rollers, consisting of a back line of fluted rolls and a front line of leather covered rolls The roping then passes through the thread or pot eye down to the spinning ring and traveler and thence to the rapidly revolving bobbin

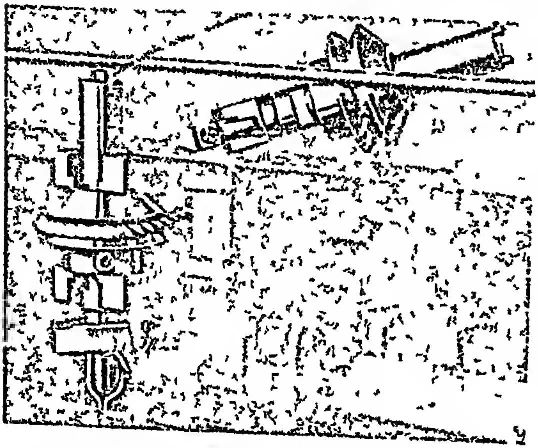


Fig 7 Close-up of patented twisterhead (*Whitin*)

Draft To find the draft on a wool spinning frame, the following formula is employed (D G means draft gear)

$$\text{Draft} = \frac{20 \times \text{D G} \times 1\ 25}{20 \times 25 \times 1\ 25} = \frac{\text{D G}}{25} \qquad \text{D G} = \text{Draft} \times 25$$

Production The production of a wool spinning frame is of prime importance The production per spindle in pounds per 10 hours, (P) can be found by using the formula given No allowance for doffing, cleaning and oiling is made

$$P = \frac{A \times B \times 600}{600 \times 36 \times R} \quad \text{or} \quad P = \frac{B \times 0409}{R}$$

P—production per spindle in pounds per 10 hours A—diameter of front roll. B—rpm of front roll R—run (size) of yarn produced

Regarding the lay of the yarn on the bobbin, it is good practice when changing a fraction of a run either way to increase the speed of the spindle rail and thus create more tension, or decrease it to reduce the tension, using the same traveler in both cases There should be just enough space between the layers of yarn that the wood of the bobbin can be seen.

TABLE 6 PRODUCTION IN WOOLEN RING SPINNING

Courtesy Whitin Machine Works

rpm of F Roll	WOOL RUNS 1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	8
35	1.43	0.95	0.71	0.57	0.48	0.41	367	318	286	260	238	220	.204	179
40	1.64	1.09	0.82	0.65	0.54	0.47	0.41	363	327	297	272	252	234	202
45	1.84	1.23	0.92	0.73	0.61	0.53	0.46	0.41	368	334	306	283	263	230
50	2.04	1.36	1.02	0.82	0.68	0.58	0.51	0.45	0.41	372	340	314	292	256
55	2.25	1.50	1.12	0.90	0.75	0.64	0.56	0.50	0.45	0.41	385	346	321	281
60	2.45	1.63	1.23	0.98	0.82	0.70	0.61	0.54	0.49	0.45	0.41	377	350	306
65	2.66	1.77	1.33	1.06	0.88	0.76	0.66	0.59	0.53	0.48	0.44	408	380	332
70	2.86	1.90	1.43	1.14	0.95	0.82	0.71	0.63	0.57	0.52	477	440	408	358
75	3.07	2.04	1.53	1.23	1.02	0.88	0.77	0.68	0.61	0.56	0.51	472	438	383
80	3.27	2.18	1.63	1.31	1.09	0.93	0.82	0.73	0.65	0.59	0.54	0.50	477	409
85	3.47	2.31	1.73	1.39	1.16	0.99	0.87	0.77	0.69	0.63	0.58	0.53	0.50	435
90	3.68	2.45	1.84	1.47	1.23	1.05	0.92	0.82	0.74	0.67	0.61	0.57	0.53	460
95	3.88	2.58	1.94	1.55	1.29	1.11	0.97	0.86	0.78	0.71	0.65	0.60	0.55	485
100	4.09	2.72	2.04	1.63	1.36	1.17	1.02	0.91	0.82	0.74	0.68	0.63	0.58	0.51
105	4.29	2.86	2.14	1.71	1.43	1.22	1.07	0.95	0.86	0.78	0.71	0.66	0.61	0.54
110	4.50	3.00	2.25	1.80	1.50	1.28	1.12	1.00	0.90	0.82	0.75	0.69	0.64	0.56
115	4.70	3.13	2.35	1.88	1.57	1.34	1.17	1.04	0.94	0.85	0.78	0.72	0.67	0.59
120	4.91	3.27	2.45	1.96	1.64	1.40	1.23	1.09	0.98	0.89	0.82	0.76	0.70	0.61
125	5.11	3.41	2.56	2.04	1.70	1.47	1.28	1.14	1.02	0.93	0.85	0.79	0.73	0.64
130	5.32	3.54	2.66	2.12	1.77	1.52	1.33	1.18	1.06	0.97	0.89	0.82	0.76	0.66
135	5.52	3.68	2.76	2.20	1.84	1.58	1.38	1.23	1.10	1.00	0.92	0.85	0.79	0.69
140	5.72	3.81	2.86	2.29	1.91	1.63	1.43	1.27	1.14	1.04	0.95	0.88	0.82	0.71
145	5.93	3.85	2.96	2.37	1.98	1.69	1.48	1.32	1.19	1.08	0.99	0.91	0.85	0.74
150	6.13	4.09	3.06	2.45	2.04	1.75	1.53	1.36	1.23	1.11	1.02	0.94	0.88	0.77
155	6.34	4.22	3.16	2.53	2.11	1.81	1.58	1.41	1.27	1.15	1.06	0.97	0.90	0.79
160	6.53	4.35	3.26	2.61	2.18	1.86	1.63	1.45	1.30	1.19	1.09	1.00	0.93	0.82
165	6.74	4.50	3.37	2.70	2.25	1.93	1.69	1.50	1.35	1.23	1.12	1.04	0.96	0.84
170	6.95	4.63	3.47	2.78	2.32	1.98	1.74	1.54	1.39	1.26	1.16	1.07	0.99	0.87
175	7.16	4.77	3.58	2.86	2.38	2.04	1.79	1.59	1.43	1.30	1.19	1.10	1.02	0.90
180	7.36	4.91	3.68	2.94	2.45	2.10	1.84	1.63	1.47	1.34	1.23	1.13	1.05	0.92
185	7.57	5.04	3.78	3.03	2.52	2.16	1.89	1.68	1.51	1.37	1.26	1.16	1.08	0.95
190	7.77	5.18	3.88	3.10	2.59	2.22	1.94	1.73	1.56	1.41	1.30	1.19	1.11	0.97
195	7.97	5.30	3.98	3.18	2.66	2.28	1.99	1.77	1.59	1.45	1.33	1.23	1.14	1.00
200	8.18	5.45	4.09	3.27	2.72	2.34	2.04	1.81	1.63	1.49	1.36	1.26	1.17	1.02

Packages Fig 8 shows the large spinning package employed on the ring frame, especially in carpet work, where 5½-in rings are used, and 11-in traverse The frame spun bobbins made on 5-in rings will hold 18-22 ounces of single yarn, while the 5-in by 9-in. twister package shown on the left will carry 35-37 ounces of plied yarns Such packages will produce decidedly fewer knots and consume less time in doffing Bobbins are now made of seasoned rock maple stock and coated with a baked enamel, which makes the wood impervious to moisture The barrel is perforated for the greater part of its length, so that even when

Fig 8 Modern spinning frame and twister bobbins (*Whitin*)

filled with yarn, ample penetration may be obtained when conditioning the yarn

Some of the advantages of spinning warp yarns on large bobbins are as follows higher speeds, hence, more production, can be attained by taking the yarn supply over-end from large bobbins Machine stoppage due to broken ends can be reduced, thus increasing running time and, consequently, production Less attention is required by machines taking yarn over-end from large packages, this makes possible a reorganization of methods and jobs, resulting in more production per dollar of wages Most of the knots in spooling and winding can be eliminated, resulting in better running and higher quality in weaving, consequently, less burling and mending are necessary and the amount of waste is reduced

Variable speeds In ring spinning, it is generally conceded that the speed at which a given yarn may be spun is limited by the speed the yarn will stand when being spun to the smallest bobbin diameter Hence it follows that, if the spindle speed and operating speed of the frame is reduced to this critical point at the beginning of the spin, full opportunity is given for a higher speed during the balance of the spin, and a higher production may be obtained

As the speed change on "filling wind" is frequent and, after the base is built, constant throughout the doff, it is found most practical to control speeds automatically from the builder arm by means of a connecting mechanism between the builder arm and the control box At the small of the bobbin, the traversing bolster rail is at its lowest point, and the builder arm is at its highest point Conversely, at the large of the bobbin, the traversing bolster rail is at its highest point and the builder arm is at its lowest point In this position, the mechanism from the builder arm to the control box is holding the control box lever at its most advanced position (farthest position, when facing the frame) As the bolster rail moves down, the builder arm rises slowly, bringing the control box lever toward the observer, cutting-in resistance and slowing down the slip-ring-type motor, and the frame This operation is reversed as the bolster rail moves up to the large of the bobbin, and the speed is gradually stepped up

To make operation fully automatic, the frame is stopped at completion of the doff when the adjusting screw contacts a knock-off switch under the ring rail When this contact is made the rail rises to doffing position, and the frame comes to a stop

While this type of drive is not recommended for all mills it is a decided advantage on certain work, as it not only gives a better spin, but also helps the quality of the yarn and increases production

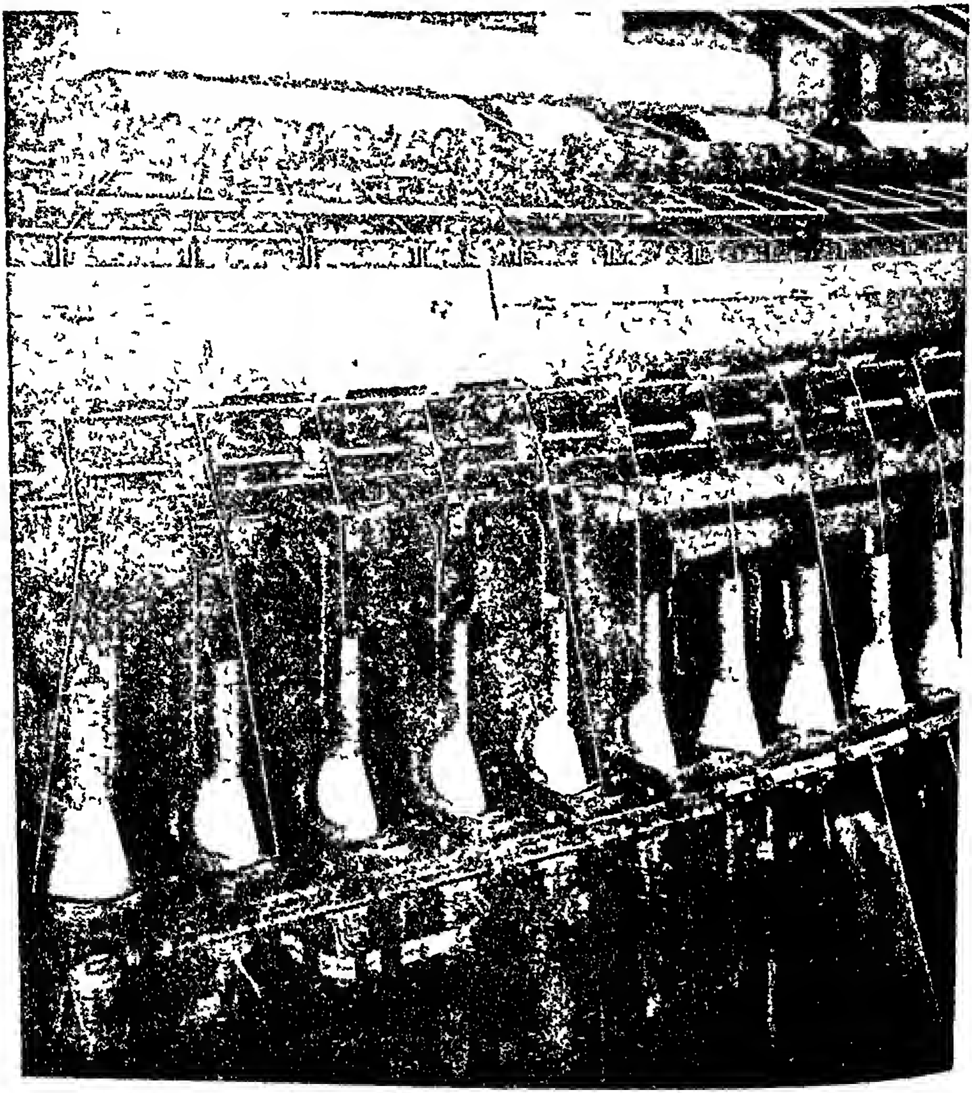


Fig 9 Whitin woolen spinning frame *Courtesy Forstmann Woolen Co*

WOOLEN AND WORSTED YARN CALCULATIONS

Woolen and worsted yarns are designated by terms such as 2 "run," 30 "cut" or 50 worsted, which are the *size, number* or *count* of any specific single yarn.

Worsted yarns Only one system of yarn numbering exists throughout all English speaking countries It is known as the "English worsted

count," irrespective of whether the yarns are spun by ring, mule or cap The size of the yarn is expressed as the number of 560-yd hanks in one pound (avoirdupois) This means that a number 10 worsted yarn would have ten 560-pound hanks or 5,600-yards per pound A number 24 worsted yarn would have 24 x 560-yard hanks or 13,440 yards per lb In other words, as the number of the yarn increases, the greater becomes the yardage per pound and the smaller the diameter

In textile calculations such as determining the yardage of plied yarns or the weight of yarn in a yard of cloth, it becomes necessary to know what size yarn was used Folded or plied yarns are numbered on the basis of the single yarn number from which they are made For instance, 2 ends of 40 single worsted yarn make a 2/40s or 2 ply 40s worsted yarn Since there are 2 ends of a 40 single worsted yarn, it is expected that the yardage per pound will be one half that of the single yarn, namely, 40 x 560 divided by 2, which is 11,200 yards The twist put into the two ply is usually in a reverse direction to the twist in the single yarn and only about ½ the amount, therefore, it has little effect on the yardage per pound, as calculated above. The same rule applies to a 3 or 4 ply yarn as long as the singles from which they are made are the same worsted yarn size If twist is put on twist, then a shortening of the yarn takes place, resulting in less yardage

The variation in diameter of different worsted yarns can be seen from the data in Table 7 showing the number of ends that can be placed side by side in one inch of cloth Although this table makes no provision for differences in weave, it is a convenient guide for fabric designers in determining the maximum number of ends per inch in a cloth

TABLE 7 DIAMETERS OF WORSTED YARNS

Counts	No in One Inch	Counts	No in One Inch	Counts	No in One Inch	Counts	No in One Inch
120	234	58	163	32	120	13	77
115	229	56	160	30	117	12	74
110	224	54	157	28	113	11	71
105	219	52	154	26	109	10	67
100	213	50	151	24	104	9	64
95	208	48	148	22	100	8	60
90	202	46	145	20	95	7	56
85	197	44	141	19	93	6	52
80	191	42	138	18	90	5	48
75	185	40	135	17	88	4	42⅔
70	179	38	131	16	85	3	37
65	172	36	128	15	83	2	30
60	165	3[illegible]	124	14	80	1	21⅓

The following rules will help to solve problems arising in the mill with respect to yarn calculations:

a) To determine the yards per pound of any known worsted yarn, the yarn number is multiplied by 560.
b) To determine the weight in pounds of a given number of yards of a given worsted yarn size, the number of yards is divided by the yarn size and the standard 560 (or the yards per pound of the known yarn).
c) To determine the yarn number when a given weight in grains for a known yardage is given, the known yardage is multiplied by 7000 (grains in one pound) and divided by its weight in grains and the standard 560.

Another approach to these calculations is as follows: One yard of a number one worsted yarn weighs 12.5 grains, therefore, 40 yards of a 40 worsted yarn weigh 12 5 grains. Now, to determine how much 12,600 yards of a 40 worsted yarn weigh in ounces, 12,600 is divided by 40, giving 315 yards. Now, 315 is multiplied by 12 5 grains, which is 3937.5 grains or 9 ounces

The International, (Continental, or Metric) system is used in Europe and by exporters and importers It is based on the multiples of weight of 1000-meter hanks in one kilogram (A meter equals 39 37 inches and one kilogram equals 2 2 pounds) To convert English worsted to metric worsted the worsted number is divided by 0 886. One yard of number one worsted yarn in the metric system weighs 14.11 grains as compared with 12 5 grains in the American system. 12 5 divided by 14.11 equals 0 886, the conversion factor.

Resultant counts. If two worsted yarns of different sizes such as 1/60s and 1/40s are twisted together, the following rule will determine the resultant count:

Rule · The product of the two given counts divided by their sum gives the resultant combined count.

Example: 1/60s and 1/40s worsted yarns are to be twisted together without allowing for contraction What is the new count?

$$\textit{Solution:}\ \frac{60 \times 40}{60 + 40} = \frac{2400}{100} = \text{No. 24s worsted}$$

Whenever three or more *unequal* worsted yarns are twisted together, the count of the resulting thread is found by dividing the highest count by itself, and each of the given counts in succession; the quotient in each case represents the proportionate weight of each thread The

highest count is then divided by the sum of the quotients The answer will be the combined or twisted count [2]

Example A 1/60s worsted, a 1/30s worsted and a 1/20s worsted yarn are to be twisted together What is the combined count?

Solution

$$\begin{array}{lcl} 60 & 60 = & 1 \\ 60 & 30 = & 2 \\ 60 & 20 = & 3 \\ \hline & & 6 \end{array} \qquad \frac{60}{6} = 10\text{s is the size of the 3-ply yarn}$$

Conversion factors The metric or Continental System of calculating worsted yarn is based on the number of 1000-meter hanks in one kilogram The American equivalent of 100 meters per kilogram is 496 yards per pound

To convert English worsted to metric worsted, divide by 0 886

To convert metric worsted to English worsted multiply by 0 886

Example What is the metric worsted for a 45s English worsted?

$$\frac{45}{0\ 886} = 50\ 8 \text{ metric worsted}$$

Example What is the English worsted equivalent of a 40 6 metric worsted?

$$40\ 6 \times 0\ 885 = 35\ 97 \text{ or } 1/36\text{s English worsted}$$

Woolen yarns In America, two yarn numbering systems are in use for woolen yarns, irrespective of whether they are spun on the mule or ring system The "run" system is extensively used in New England woolen mills A *run* is the number of 1600-yard hanks in one pound or the weight of 20 yards in grains That is, a four-run woolen yarn would have 4 x 1600 or 6,400 yards per pound, or, one yard of a one-run woolen yarn weighs 4 375 grains, therefore, one yard of a 4-run yarn would weigh 4 375 grains divided by 4 or 1 094 grains Now to obtain the number of yards per pound, 7000 grains per pound is divided by 1 094, to give 6,400 yards per pound

The other system is the "cut" system used in and around Philadelphia It is based on 300-yard *cuts* or hanks per pound, which constitute a one cut woolen yarn A ten cut woolen yarn would have 10 x 300 or 3,000 yards in one pound

In order that a comparison of these different yarn systems may be made Table 8 has been prepared In addition to the usual run and cut

[2]Comparative yarn table gives such conversions directly

systems used in the woolen and worsted trade, the denier, Typp and Grex equivalents are given

TABLE 8 YARN NUMBER CONVERSION TABLE

Typp 1,000 yd *per lb*	*Woolen* *Cut* 300 *yd per lb*	*Woolen* *Run* 1600 *yd per lb*	*Worsted* 560 *yd per lb*	*Metric* 1,000 *meters per kg*	*Denier* *Grams per* 9,000 *meters*	*Grex* *Grams per* 10,000 *meters*
0.30	1.00	0.19	0.54	0.61	14,890	16,540
0.50	1.65	0.31	0.89	1.00	9,000	10,000
0.56	1.87	0.35	1.00	1.13	7,972	8,852
1.00	3.33	0.63	1.79	2.02	4,465	4,961
1.60	5.33	1.00	2.86	3.23	2,790	3,100
2.00	6.67	1.25	3.57	4.03	2,232	2,480
4.00	13.33	2.50	7.14	8.07	1,116	1,240
4.46	14.88	2.79	7.97	9.00	1,000	1,111
4.96	16.53	3.10	18.86	*10.00*	900	*1,000*
6.00	*20.00*	3.75	10.71	12.10	744	827
8.00	26.67	*5.00*	14.29	16.13	558	620
10.00	33.33	6.25	17.86	20.16	447	496
15.00	*50.00*	9.38	26.79	30.24	298	331
20.00	66.67	12.50	35.71	40.32	223	248
40.00	133.30	*25.00*	71.43	80.65	112	124
44.64	148.30	27.90	*79.71*	90.00	*100*	111
49.60	165.30	31.00	88.58	*100.00*	90	100
60.00	*200.00*	37.50	107.10	121.00	74	83
89.29	297.60	55.81	159.50	180.00	*50*	56
99.21	330.70	62.01	177.20	200.00	45	*50*

A S T M[3] has suggested another method for calculating and converting yarn numbers as follows

To calculate yarn numbers from the weight of 120 yards in grains use the following formulas.

Indirect (reciprocal) Systems

$$\text{Yarn number} = \frac{C}{W} \text{ where}$$

W = weight of 120 yd. in grains, and

$$C = \begin{cases} 525 \text{ for Wool run} \\ 840 \text{ for Typp} \\ 1500 \text{ for Worsted} \\ 1694 \text{ for Metric} \\ 2800 \text{ for Linen and Woolen cut} \end{cases}$$

Direct Systems

$$\text{Yarn number} = W \times C \text{ where}$$

W = weight of 120 yd. in grains, and

$$C = \begin{cases} 5.315 \text{ for Denier} \\ 5.905 \text{ for Grex} \end{cases}$$

[3] The American Society for Testing Materials

Atmospheric Conditions in Wool Manufacturing

Theory as well as practice has demonstrated that certain atmospheric conditions are required in all departments of a woolen or worsted mill In most modern mills this is accomplished by complete air conditioning in which the temperature, moisture or humidity and air currents are predetermined and under constant control Surveys such as were recently made in Australian and American mills have shown that wide variations exist throughout the industry In setting up standards of procedure in this work, the comfort, efficiency and health of the operatives had to be considered, as well as the need for ideal processing conditions Elimination of static electricity, reasonable indoor temperatures, correct moisture regain in the stock or product and the general climatic conditions of the area where each mill is located are essential factors

One of the most important points to consider is the provision and maintenance of sufficient moisture in the wool fibers to keep them pliable and resistant to the rubbing, mixing, drawing and twisting to which they are subjected during their conversion into yarn and fabric The rubbing and winding tends to produce in the fibers frictional electricity (often referred to as static electricity) which can cause endless difficulties and production delays The electrical charge causes the fibers to repel or attract one another or to cling to parts of machines, resulting in interruption of machine operation and yarn breaks The slivers, rovings and yarns emerge with a bearded, fuzzy appearance and a liveliness which is so objectionable that it must be prevented at all costs

Another important factor is that high machinery speeds and the general acceleration of production create heat, especially in spinning rooms, which dries out the moisture in the wool and the surrounding air This moisture must be replaced in some manner or the dryness increases to an undesirable degree

Methods have been found to control static electricity, temperature and moisture conditions These conditions are not the same for all processes and Table 10 shows how they vary in the different departments of a woolen or worsted mill While this table does not show exact conditions, it does give a general indication of American practice at the present time and shows that French worsted mule spinning and woolen mule spinning require the highest humidities

TABLE 10 RECOMMENDED HUMIDITIES FOR WOOL PROCESSING AT 75°-80°F

Departments		Per cent Humidity
Raw Wool Storage		50-55
Mixing and Blending		65-70
Carding		
	Worsted	60-70
	Woolen	60-75
Combing, Worsted		65-75
Drawing, Worsted		
	Bradford System	50-60
	French System	65-70
Spinning	Bradford Worsted	50-55
	French (Mule)	75-85
	Woolen Mule	65-75
Winding and Spooling		55-60
Warping, Worsted		50-55
Weaving, Woolen and Worsted		50-60
Perching or Clothroom		55-60

Woolen and worsted mills have concentrated on the control of humidity in the various departments as one means of keeping moisture in the stock, this, in turn, reduces the temperature of the room and most of the time, although not always, minimizes static electricity without interfering with the operatives' health, comfort and efficiency Moisture can be added to the room air by providing it in the form of vapor or finely divided mist or droplets, which readily disperse and evaporate Humidifiers, atomizers and sprayers are available for this specific purpose They are automatically controlled and can be adjusted to suit any of the current conditions It has been found that if the regain of the processed stock falls below 12 per cent in any process, trouble from static electricity may be expected It is generally agreed that the ideal conditions for wool processing are ordinarily obtained at temperatures between 75 and 80°F and relative humidities from 50 to 55 per cent, except in spinning woolen and worsted yarns. (See Table 10)

A study recently made in Australia[4] showed that various conditions for the comfort of operatives and satisfactory processing exist These are illustrated by Figures 10 and 11, in which critical comfort and process lines are indicated for all wool processing, as well as the critical and optimum regain

[4] *Atmospheric conditions in Australian textile mills* Comm of Australia, Dept of Labor & National Service Bulletin No 6 (1945)

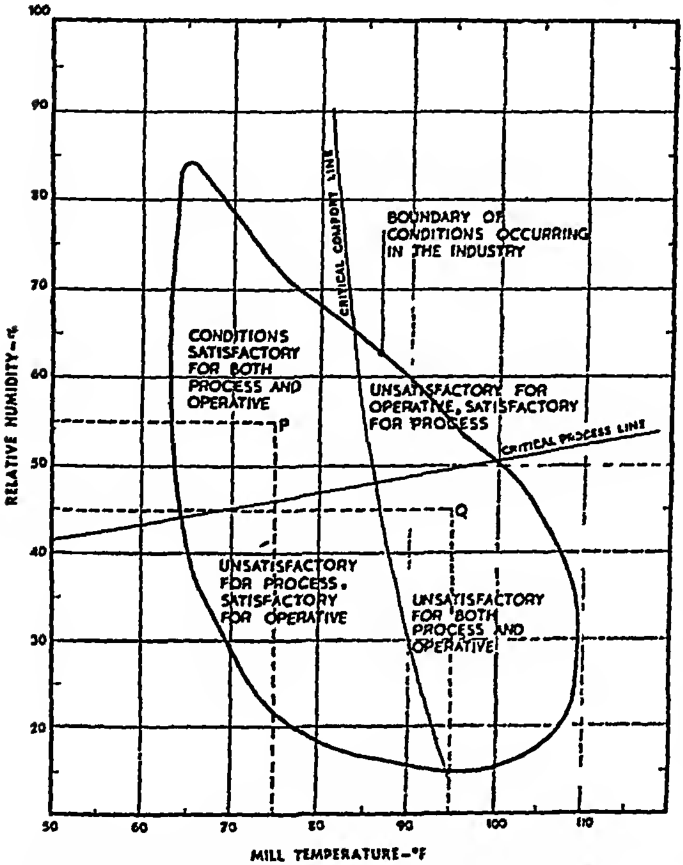


Fig 10 Chart of mill temperature and humidity conditions showing critical comfort and process demarcation lines

In some processes such as carding, garnetting and warping and where no humidity control exists or can be used in a mill, static eliminators or neutralizers are used to prevent static from interfering with proper functioning These devices consist of inductor bars placed directly over or under the roving, and a power unit, which is a transformer operating at 110, 220 or 440 volts AC One terminal of the secondary coil is connected to the ground and the other to a well insulated cable leading to the inductor bars which neutralize the electric charge on the roping or stock The operating cost of such a neutralizer is little more than that of an ordinary light bulb (Chap 10, Fig. 27, p479)

If these neutralizers are not used and the stock dries out from lack of moisture or excessive heat, as occurs in drying stock, yarn or goods, the electric charges set up on the material will cause sparking and can cause fires and accidents to operatives from electric shocks

Relative humidity and regain Humidity is a measure of the amount of water held in the vapor state by the air. In vaporizing the water from the humidifiers, a portion of the heat content of the air is expended.

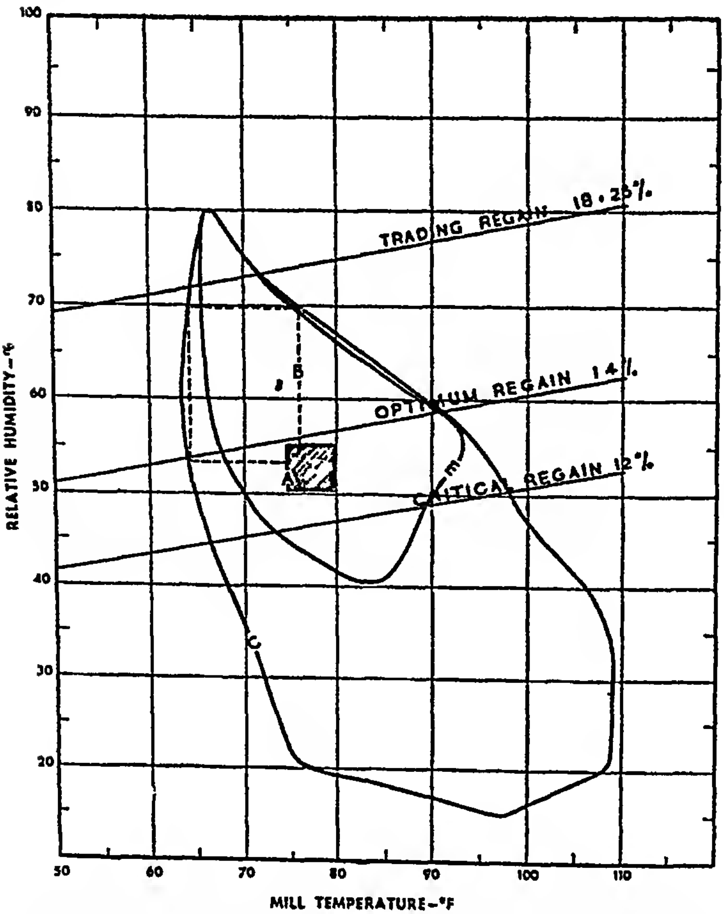


Fig 11 Chart of mill temperature and humidity condition showing critical, optimum and trading regain areas

Thus the humidifying process cools the air, as well as adds to its water content This cooling process, in hot weather, also improves conditions for operatives. If humidifiers have a sufficient capacity and run continuously, it is possible for them to discharge more water than the air can absorb When this point has been reached, the additional fine spray of water will settle on objects in the room, like a dew The point at which this takes place is called the *dew-point.*

Humidity is measured in two ways· as *absolute* humidity and as *relative humidity* Absolute humidity is a measure of the weight of water in the air, irrespective of temperature It is expressed in grains per cubic foot The quantity of water which air may hold increases with increasing temperature. An example of this is shown in Table 11 which gives the maximum grains of water one cubic foot of air will hold at certain temperatures[5] Note how, at 70°F, the capacity is nearly three times that at 40°F, and that at 100°F the capacity is about double that at 70°F Thus it can be seen that to give the grains of

[5] *Air Conditioning in Textile Mills,* A W Thompson, Parks-Cramer Co 1924

TABLE 11 WATER CONTENT OF AIR AT VARIOUS TEMPERATURES.

Temperature	*Grains of water per cubic foot*
40°F	2.86
70°F	8 07
100°F	19 97

water per cubic foot of air is not enough It is also necessary to give the temperature of the air.

The amount of moisture which wool will absorb from any given atmosphere does not depend upon the grains per cubic foot, but rather upon the per cent of moisture in relation to the temperature Because of this, the manufacturer is more interested in *relative* humidity than in *absolute* humidity.

Relative humidity is a measure of the moisture contained by any atmosphere expressed as a per cent of the total possible moisture content at a given temperature. Thus, air holding 2 86 grains per cubic foot at 40°F. has a relative humidity of 100 per cent However, if the temperature of the air is raised to 70°F while the moisture content remains at 2 86 grains per cubic foot, the relative humidity becomes 35 5 per cent because, at 70°F, the air could hold 8 07 grains of water as vapor. Again, if the temperature is raised to 100°F with 2 86 grains per cubic foot, the relative humidity drops to 14 3 per cent The above example serves to illustrate what happens in cold weather If there is 100 per cent relative humidity in the outside air at 40°F, when drawn into the mill and heated to 70°F, its relative humidity drops to 35.5 per cent and, as the air is heated to a higher temperature, the relative humidity is even less This shows why it is quite important to have humidifiers to maintain the desired relative humidity

The amount of moisture which is present in wool fibers is expressed as *per cent moisture* or *per cent regain.* Per cent moisture is just what the words indicate, the per cent of the sample which is water Several of the characteristics of wool vary with the per cent of moisture and research has shown that the relation is directly in proportion to the per cent of water expressed as a per cent of the dry wool itself This is the reason for using the term *per cent regain.* The expression was developed on the basis that the wool was baked until dry and then permitted to regain the normal moisture for any given atmosphere and humidity

The term *condition* is used when speaking of the moisture in wool Any wool material is *conditioned* by allowing it to stand in the desired relative humidity for a sufficient length of time to come to constant weight Custom has established a relative humidity of 65 per cent at 70°F. as a *standard atmosphere* in which samples should be exposed long enough to attain the normal moisture content for that relative humidity. This, however, is for testing purposes and samples from manufacturing operations are rarely at this condition.

Measurement of relative humidity The relative humidity prevailing in any mill room is determined with the help of a sling psychrometer, which is a pair of thermometers mounted on a special frame so they may be rotated rapidly. A cloth wick saturated with distilled water surrounds the mercury bulb of *one* thermometer and is called the *wet bulb* thermometer. The other is called a *dry bulb* thermometer. Rapid evaporation of water from the wick, as the thermometer is whirled, reduces the temperature of the wet bulb thermometer. The rate of evaporation depends upon the relative humidity of the atmosphere If the air is very dry, the evaporation is very rapid and the wet bulb temperature is considerably below that of the dry bulb By referring to a table of differences, often called *wet bulb depressions,* it is possible to determine the relative humidity directly.

on mules, but during the last 40 years there has developed a considerable shift to ring spinning frames, until now a very large portion of it is ring-spun.

The flow sheets, Figs 1 and 5 show the general comparison between the Bradford and French systems, as well as the intermediate steps.

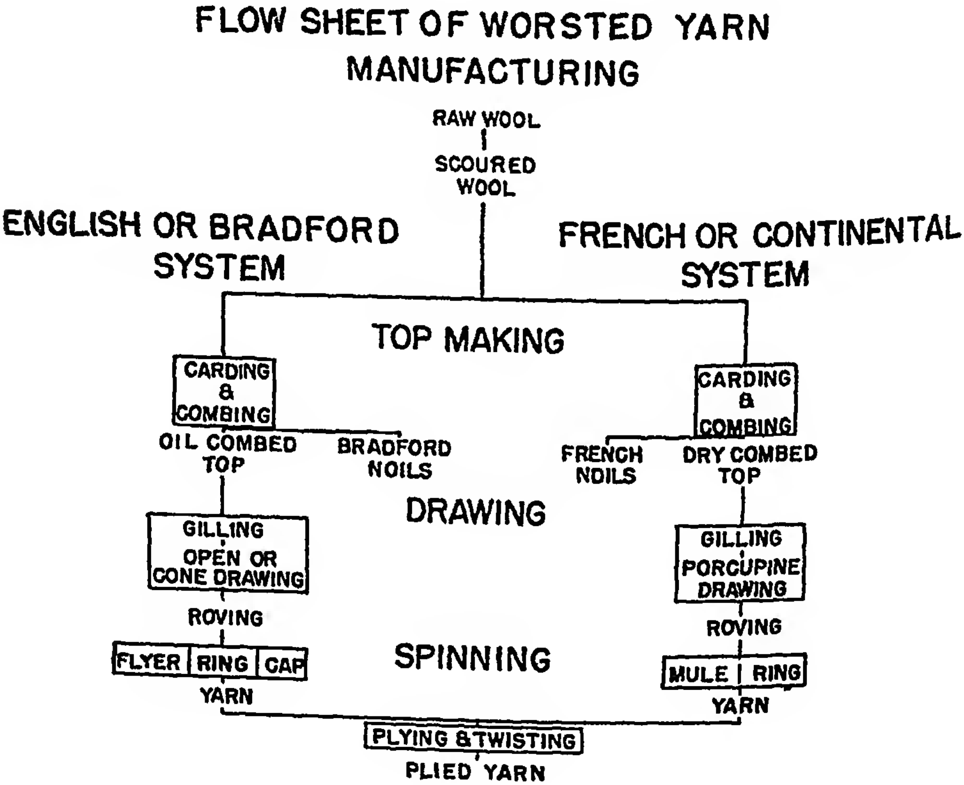


Fig. 1

Not shown on the flow sheet, but of growing significance during the past few years, is a third system of worsted spinning known as the American System. This system was developed by the Whitin Machine Works as an outgrowth of their work on equipment for spinning rayon staple. A short staple Bradford or French combed top containing about 2 per cent of oil is used on this simplest of worsted systems, which consists of three open drawing operations, one long-draft roving operation, and finally a ring spinning frame.

WORSTED CARDING

After scouring, drying, and otherwise preparing long or short qualities, including the dusting and shaking of cotty or sandy wools, and the opening and teasing of cotty and lumpy wools, they are ready to be fed into the worsted card for eventual worsted-top production

Worsted carding goes further than woolen carding The objects of worsted carding are

1 To straighten and separate and, in general, to make the long wool fibers lie parallel

2 To clean the fibers, that is, to remove burrs, shives and other extraneous vegetable matter

3 To blend, distribute, and mix the different lengths and qualities harmoniously into one quality

4 To arrange the fibers into a continuous and convenient sliver of definite weight and thickness

In worsted carding it is very important to straighten the crimpy long fibers and keep them as far as possible in a parallel position and to have an even distribution of long and short fibers in the sliver. Great care is taken to accomplish these objectives thoroughly or an uneven top and yarn result Since worsted yarns are distinguished by strength, uniformity of spin, and great fineness with a consequent higher cost, every precaution must be taken in carding to attain these objectives. The long wool fibers must not be broken off unnecessarily or reduced in length, the short fibers must not be allowed to curl up, accumulate, and form neps, bunches, slubs, or balls

Whereas the woolen carder is more concerned with sufficient blending, the worsted carder, because of later drawing operations, must be more concerned with the parallelism of the fibers Hence, he is limited to lower speeds and requires a larger carding surface, here his concern is with the long fibers rather than the short, because the latter are combed out later Side drawing and intermediate feeding devices are therefore unnecessary and all the carding required is performed on one long card, rather than on the three different cards of the woolen system

In the United States, three types of cards are in general use

1 The single-cylinder worsted card, with four licker-ins for long staple wools (Bradford system)

2. The double-cylinder worsted card, with two licker-ins and dividers for medium crossbred wools (French and Bradford systems).

3 The double-cylinder worsted cards, with burr breastworkers and strippers for fine burry wools (French system).

For fine and crossbred wools, irrespective of the system of drawing or spinning used, American worsted mills prefer the double-cylinder card.

The preliminary breastworks, as pointed out above, may consist of four licker-ins or a metallic breast, as the individual carder prefers No definite preference exists for either one of the two methods of opening the wool stock; in fact, great differences of opinion are held regarding them. The main factor in the choice of a metallic breast or of fillet-covered licker-ins in the worsted card is the amount of fiber breakage and the shortening of the carded fiber.

American worsted cards are generally of all-iron construction, rigidly built and relatively light in weight. Main cylinders are cast iron, metallic workers are aluminum, and strippers are steel tubing. The standard card widths are 48, 54, and 60 inches Of these the most common is the 60 inch width and 60 inch diameter of the main cylinders because of its increased carding surface and number of workers Worsted cards have been built as wide as 72 inches. They occupy a floor space from 22 to 36 feet in length and 6 to 7 feet high.

The production of a worsted card varies with the speed at which it can be safely and advantageously operated and the type of wool that is being handled It varies from 60 to 80 pounds per hour on long, crossbred wools and from 30 to 45 pounds per hour on fine merino wools, with cylinder speeds of 90 to 125 r.p m. on 50 inch widths One authority states that a production of 100 pounds per hour is possible on long, strong wools, such as Scotland and Iceland, on a 60- by 60-inch single-cylinder card with a 42-inch clothed breast. Even greater productions are claimed for the Proctor all-metallic-wire worsted cards

Of course, the product of a card is judged by the amount of noils it produces in the comb and by the number of neps in the sliver; everything else being equal, close co-operation between carder and comber is necessary for a minimum of noilage in combing.

Arrangement of a worsted card. A worsted card generally consists of series of rollers of various diameters which have different

speeds and directions of motion A card may be said to be divided into three main parts or sections

1 The feeding section
2 The worsted carding machine proper
3 The delivery section

1. The Feeding Section of a Worsted Card

The feeding of the wool stock to the worsted card is generally accomplished by automatic hopper feeders The stock is blown from the dryer to large bins or stockrooms from where the stock is trucked to the hoppers of feeders One operator is generally used to keep the hoppers full at all times, this job requires his attention at given periods Feeding devices are now almost entirely automatic in operation and serve to keep every yard of card sliver exactly the same in thickness and weight per unit length Previously the wool was fed by hand on a feed apron leading to the feed rolls Since it is practically impossible for a hand feeder to judge by feel or eye whether he is feeding the right amount of wool at all times, this practice resulted in a constant change in the delivered sliver weight No amount of practice can do as well as an automatic hopper feed for worsted cards

Feeding devices are not only great labor savers but also cut down variations to a minimum They are now very sensitively constructed, so that the slightest change in the sliver weight can be obtained accurately and quickly. They consist of a large hopper in which the scoured wool is placed The wool soon encounters the spikes of a vertically moving lattice apron which carries the loose fluffy bunches of wool upward; while moving upward the wool must pass an oscillating beater comb so adjusted to the lattice apron that no large lumps pass this point, nor any more wool than is required The beater comb serves to distribute the quantity of wool over the whole width of the lattice and the wool then passes on over the top of the hopper when its spikes point downward At this point the wool is beaten off by a fast-moving rotary beater, which drops or beats the wool into a scalepan or tin container extending the whole width of the card and located directly over one end of a horizontal lattice-feed apron. When sufficient wool is deposited in the pan, usually about ½ pound, it stops the vertical apron by means of a beam and the pan bottom automatically opens up and [illegible]

exact quantity of wool is deposited on the slowly moving, horizontal, lattice-feed apron Here, it is dabbed down uniformly by a dabber and is moved forward by a wooden pushing-up board so that it will occupy a definite number of inches on the feed apron Hence, ½ pound of wool will occupy 8 inches of space, for instance, and therefore, the amount of wool going into the card is definitely controlled This dumping of the contents of the scalepan can be timed, for instance, once every 45 seconds The whole automatic hopper feeder is carefully timed and driven in direct connection with the feed rolls of the card These devices are all patented, and they differ only in minor

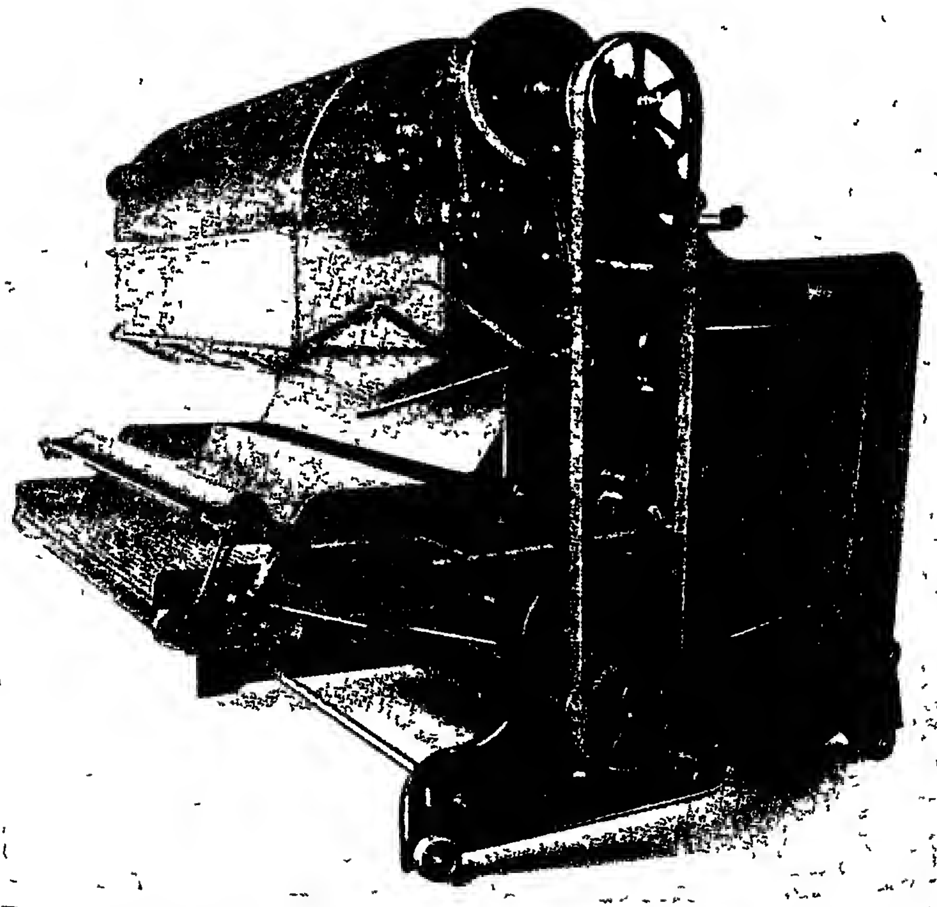


Fig. 2 Modern automatic-weigh feeder. (*Courtesy Whitin Machine Works*)

construction details A typical modern worsted-carding hopper feeder is shown in Fig. 2

Practically all worsted cards are today equipped with these automatic-weigh feeds, as they are known in contrast to the ordinary hopper feeds which do not weigh the amount of wool fed into the card Adjustments to alter the amount of wool going into the card are made at the weigh beam and also by adjusting the oscillating beater on the vertical, spiked-lattice apron

2. The Worsted Carding Machine

The worsted carding machine proper generally consists of the following parts

1 feed rollers.
2 breastworks, burr cylinders, or licker-ins
3 main cylinders and their workers and strippers
4 fancies
5 doffers
6 dickeys

1 Feed rollers The first parts of a worsted card are the feed rollers, which control the feeding of the stock to the card They are clothed with inserted saw-tooth wire or fitted with brass rings and intersecting steel pins Generally two feed rollers, with one stripper clothed with wire or brush fillet, are used for crossbred wools, but for fine qualities three rollers and one stripper roll are preferred because this arrangement retains the wool longer for a better opening Townend and Spiegel[1] found that by the use of four lines of feedrollers fiber breakage is considerably lessened Feed rolls are usually 2 to 3 inches in diameter and make about 2 to 3 r p m.

2 Breastworks The most important preliminary apparatus on a worsted card is the breastworks with its feed rollers, licker-in, burr cylinder, and, if needed, its burr guards, which control to a large extent the proper opening of the wool stock The breastworks or licker-ins constitute the chief opening elements of the stock in a worsted card, depending on the general condition and quality of stock run on each card This section of the worsted card used to be known as the preparers The longer the wool the more preparers or licker-ins (also known as taker-ins) were necessary This theory has now been discarded in favor of breast-

[1]Townend, J and Spiegel, H H, *J Textile Inst*, 37, T58-76, March 1946

works and burring attachments for short burry wool Since many mills are still equipped with licker-ins (from three to five in number and with top and bottom dividers) it will be appropriate to explain their action These cylinders vary in diameter from 20 to 30 inches They are covered with inserted metallic garnett wire and angular teeth made flat on top to reduce the spaces or indents with the object of keeping the burrs, shives, and other extraneous matter on the surface, so that the bladed burr-beaters can remove them Round wire between the metallic wire serves the same purpose. A common metallic wire is an 18 by 24 diamond-point wire on the first licker-in Succeeding licker-ins are now metallic-wire-covered, whereas in the older cards coarse filleting of No 24, No 26, and No. 30 wire was used

Whenever wool stock has mestiza or spiral burrs and other foreign matter* in fairly large quantities it becomes necessory to use a burr cylinder or automatic burr cleaner preceding the preparers or licker-ins, or to substitute the burr breastworks entirely in place of them Such a burr breastworks is shown in the chapter on woolen carding (page 459). Various machinery builders offer different devices for this purpose In English cards a Morel wire-covered roller, usually about 27 inches in diameter, is substituted for the third licker-in Its purpose is to allow the fibers to be brushed into spaces between the rows of wire, leaving the burrs on the wire surface to be beaten off by the burr-beater

American worsted mills use a burr cylinder breastworks covered with flattened burr wire (as shown in the list of garnett wires on page 460) on which operate bladed steel burr rollers set closely to this burr cylinder They revolve at high speeds and, being set closely to the burr cylinder, knock off the burrs protruding from the garnett-wire surface into a tray. The burrs, which are larger than the staples of wool and do not penetrate the card clothing, are carried on the surface A scraper knife or brush cleans the burr trays at periodic intervals and deposits the accumulation in a high can at the side of the card

The number of these burr cylinders and bladed rollers depends on how thoroughly the burrs are to be removed and the quantity present in the stock These are the only devices used in the United States for the mechanical removal of burrs in worsted wools. In England the Harmel burr-crushing apparatus is used also, but it has found little interest here If extreme numbers of burrs are present in the stock, it should be subjected to the chemical method of carbonizing instead of depending on the more

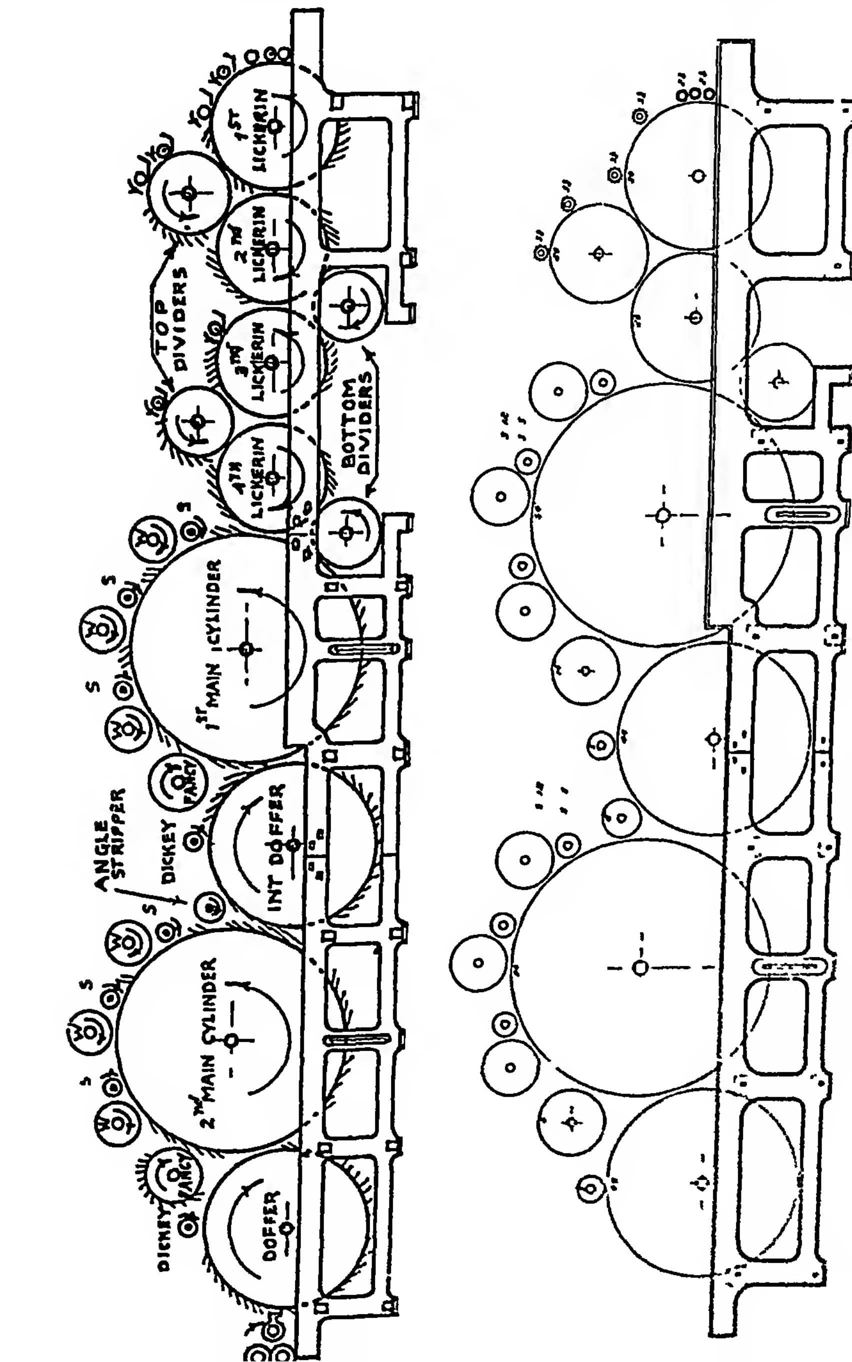


Fig. 3 *Above* Complete details of a double-cylinder worsted card with burr breastworks showing direction of rotation and wire points

Below Double cylinder worsted card with two licker-ins and dividers

(*Courtesy Davis & Furber*)

or less unreliable mechanical removal in the cards. These burrs to some extent injure the clothing, especially if they go beyond the burr breastworks.

3. Main cylinders or swifts The stock having been prepared and opened sufficiently and freed of burrs, if any, it can now be subjected to a thorough carding by the main cylinder with its workers and strippers. Typical American card constructions are shown in Fig 3, which illustrate a typical setup for worsted carding of long and short combing wools.

Both types of cards illustrated are extensively used in the United States The first one is a 60-inch diameter double-cylinder worsted card with a 36-inch burr-cylinder breastworks and one licker-in, this type is particularly preferred for the French system The diagram above shows all the details of a double-cylinder card with four licker-ins and top and bottom dividers The card shown in the lower illustration is preferred in the Bradford system for cross-bred wools

4 Action of fancy: After the wool has been thoroughly carded and returned to the main cylinders, it becomes fluffy and voluminous It is the function of the fancy to raise the carded fibers to the top of the wires of the main cylinders and allow the doffers to remove them The location of the fancy is usually above the doffer, provided with a hood to prevent fly and wind to upset the operation on account of its high speed See Figure 3. The wire of the fancy is long and its surface speed must be in excess of that of the main cylinders Its wire points opposite to its direction of rotation and is back against back with the cylinder wire, strictly a raising action. The fancy is 10-12 inches in diameter and revolves at 900-1200 r p m usually adjusted to suit the speed of the cylinder and the kind of wool running in the machine

5 Action of doffer The doffer serves the purpose to take the carded and raised stock from the main cylinder in a uniform web deposit on its wire surface Working in connection with the doffer is an oscillating doffer comb, which takes the fiber web from the same and from which it passes through a funnel to the drawing-off rolls

6 Dickeys and doffer dickeys. These are employed only in worsted cards and are small rolls covered with long, flexible-toothed, card clothing which, working against the doffer, raise any stock that may have passed the comb, and hence is removed on the next revolution Another advantage of a dickey is that it prevents shives or other foreign material from remaining in the clothing of the doffer, and keeps the wire sharper and in a much better

condition The action is about the same as an ordinary fancy

Worsted card clothing Concerning the card clothing employed in worsted cards, rubber-faced, five- to eight-ply filleting is used practically exclusively, sheet clothing is not employed at all in the United States There is a recent tendency to use a special garnett wire on worsted cards It is clothed with metallic wire throughout and the arrangement of rollers shown in Fig 3 is departed from for the first time in the United States Figure 4 shows the arrangement of the rolls and other details of this metallic worsted card, which is used mainly on crossbred wools It has no licker-in and dividers, usually considered necessary The machine also employs smaller rollers and cylinders, exactly half the size of the card just described The builders claim reduced fiber breakage, fewer neps and less vegetable matter in the card sliver, almost double the production, and no stripping or waste made from stripping Grinding is done away with completely Half the floor space is required and less power is consumed Sets have also been installed for the woolen system on carpet wools and asbestos The factors responsible for the formation of neps in worsted carding

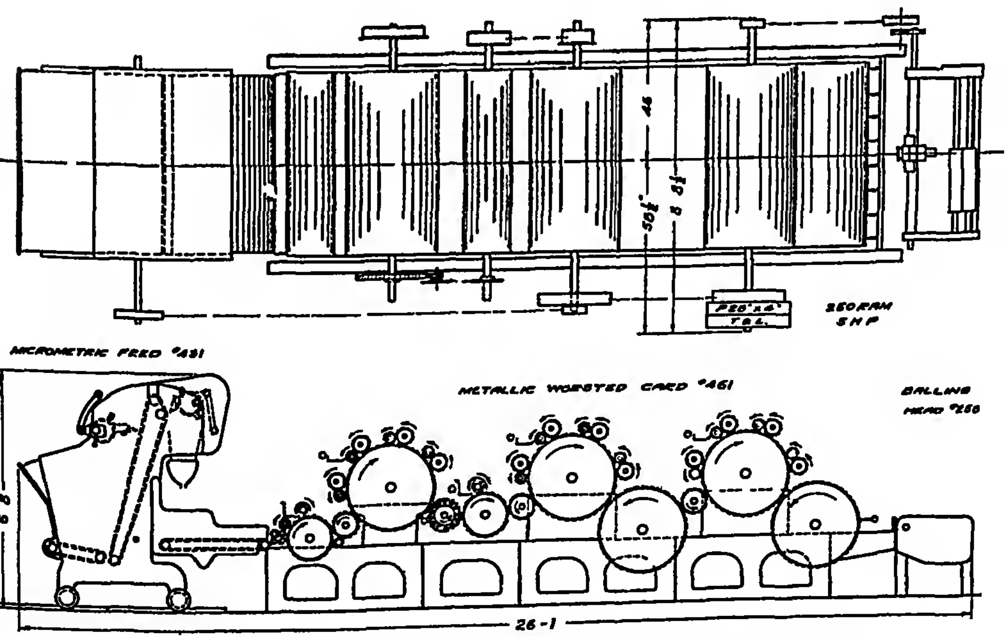


Fig 4 Metallic worsted card (*Courtesy Proctor & Schwartz*)

leading to increased noilage in combing have been investigated by Townend and Spiegel[2] They found that the most important cause of nep formation is undoubtedly the tangled nature of the scoured wool normally fed to the card, for when pulled-up tops are carded the sliver is practically free from neps. It was found that the neppiness of the carded sliver is at a minimum when the regain of the feed wool lies between 30 and 50 per cent In addition, if the amount of residual soap in the wool exceeds 0 5 per cent, the neppiness is accentuated, just as it is when the amount of added oil exceeds 1 per cent The presence of burr in scoured wool is without influence on neppiness, except in so far as it necessitates the use of burr beaters, which promote nep formation

As regards mechanical alterations to the machine, the nep content of the carded sliver decreases with increasing speed of the card as a whole, but an increase in throughput leads to a higher nep content On the other hand, a reduction in the relative surface speed between feed rollers and first licker-in causes a reduction in neppiness. A further factor of importance is the setting of the workers to the swift, the closer these rollers are set to each other, the clearer is the sliver Assuming a constant worker-swift setting, however, any alteration to the setting of the licker section is not reflected in the nep content of the sliver

The action of the dividers, in reversing the direction of the wool at the divider-licker point of contact, is responsible for a fair proportion of neps, and the ratio of the surface speeds of fancy and swift is highly critical If the fancy runs at a surface speed higher or lower than the critical value, there is a large increase in the nep content of the sliver As would be expected, too, grinding has a great influence on neppiness, a newly ground card reduced the nep content to half the number present in a sliver produced immediately before grinding

Grinding worsted cards. Regular worsted cards are best ground by using traverse grinders with 9-inch wheels in the following places

Single worsted cards with breastworks and two licker-ins one over second licker-in, one in angle stripper bearing for main cylinder and breastworks cylinder, one over doffer, and one with solid emery wheel for burr cylinder and first top divider

Double worsted cards with four licker-ins One over each of the second, third, and fourth licker-ins One on the first cylinder fancy arm for the first main cylinder One in angle stripper bearing for the first doffer and second main cylinder One over second doffer and

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[2]Townend, J and Spiegel, H H *J. Textile Inst*, 35, T-17-40, March 1944

one with solid emery wheel for burr cylinder and first top divider

For 10-inch wheels traverse grinders are used in the following places Double worsted cards with four licker-ins · one over each of the second, third, and fourth licker-ins, one each in special grinder shanks for first and second main cylinders, one each in special grinder shanks for first and second doffers, one with solid emery wheel for burr cylinder and first top divider The surface speed of the grinding wheel should not exceed 1900 feet per minute at about 500 r p m

Information regarding stripping, setting, and other grinding details is to be found in the chapter on woolen carding

3. The Delivery Section of a Worsted Card

The delivery of the stock from a worsted card is done by several means

1 a side-drawing balling head
2 a center-balling head
3 a railway-balling head
4 a can-coiling head

The sliver generally leaves the doffer of a worsted card in the form of a web which is as wide as the doffer This is gathered over a curved brass arm, and is compressed by a trumpet or funnel and a pair of calender or delivery rollers The most common delivery is the worsted balling head This system collects the stock in a right-angle balling head which is equipped with a revolving sliver tube, for inserting a mock twist, and a traveling sliver apron The whole bobbin, which has no heads and is about 18 inches wide, traverses back and forth, giving a cross-wind to the bobbin When full, the central wooden core is taken out and replaced on the bobbin head, leaving the full bobbin There are several types of these balling heads, among them the center- and side-balling heads For average wools the center-balling heads are the most commonly used in the United States, whereas for low crossbred wools, mohair, camel hair, etc , which require support, a side drawing is preferred

The railway-balling head is used extensively on the French system Slivers from seven or eight cards are collected on one conveyor belt and delivered to a balling gear at the end of the group The railway-balling aids in mixing the stock from the various cards but is only advantageous if a number of cards can be run on the same stock to save considerable labor.

The most recent method of sliver delivery is to take the sliver as

it comes from the doffer and condense it well by means of a funnel or trumpet through a pair of heavy calender rolls into a coiler; this coiler serves to deliver the untwisted sliver into a high (or deep) round fiber can The usual way is to lay the sliver in circles against the side of the can, leaving a hole in the center The can and the sliver rotate at the same time The cans are 14 or 18 inches in diameter, and 36 or 42 inches deep This can-coiling head method is preferable because the sliver receives less handling, and is more easily manipulated in the following drawing and backwashing processes

The object of each of the delivery heads described is to put the sliver into a convenient form in which it can be handled efficiently in the processes which follow. The sliver itself should be uniform in weight, yard after yard, day in and day out, machine to machine Long and short fibers must be blended uniformly, all fibers should be as nearly parallel as possible, and lumps or slubs present due to piecing eliminated as much as possible All burrs or vegetable matter, as well as neps, are to be kept to a minimum. Length of staple is very important in worsted carding and as much of the staple length as is consistent with good carding practice must be preserved

The usual sequence of operations in the Bradford system from this point on are:

1 Backwashing.
2 Gilling or preparing
3 Punch or ball winding.
4 Combing (principally by the Noble comb)
5 Gilling· (a) Finisher (b) Top box
6. Worsted-top.

These processes will be taken up in detail Many of the gilling processes are duplications of the same process and principle, repeated only to attain uniformity and the desired weight of sliver (See Fig 5)

1 Backwashing

After the long wools generally employed in the Bradford system have been properly carded (or as in mohair and coarse luster wools, prepared on sheeters, can gill boxes, etc) they are usually subjected to a backwashing This process is necessary only when the sliver looks grayish, discolored or dirty, or when large amounts of dust and impurities have been picked up after the scouring, in carding, and in some of the preparing processes The impurities removed in back-

FLOW SHEET FOR TOP MAKING

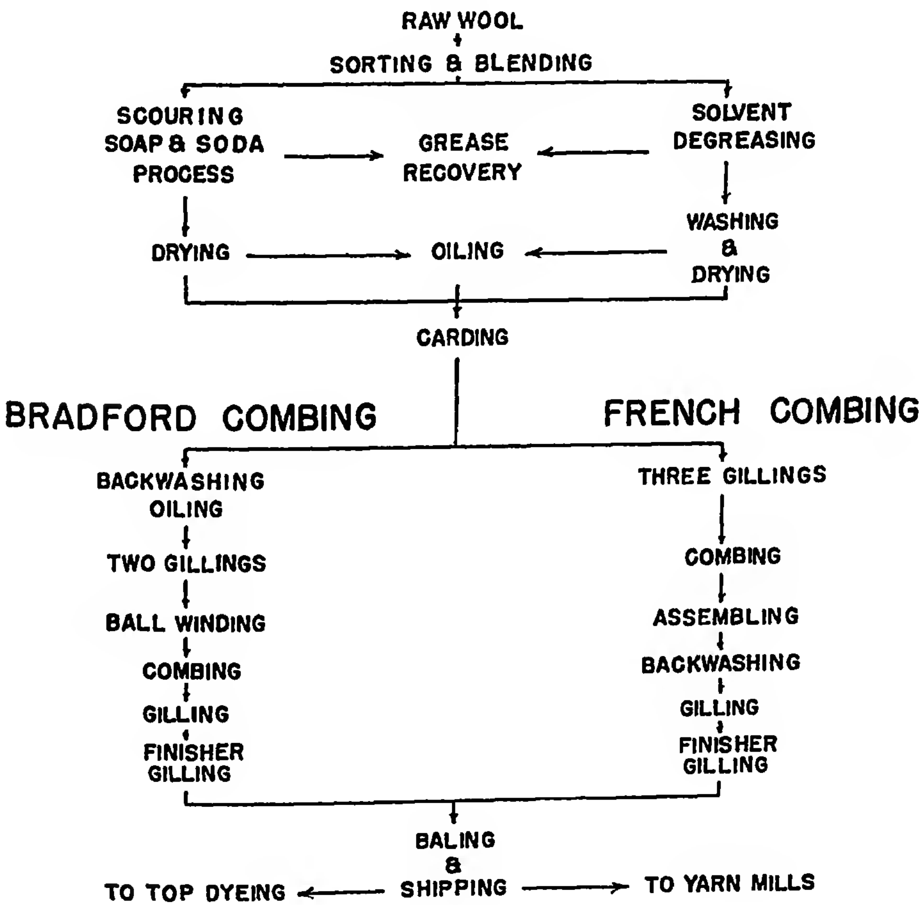

Fig 5

washing may be grouped into two classes first, acquired impurities, and second, concealed impurities

The acquired impurities consist of metallic dust and dirt gathered during carding or preparing The concealed impurities are those which scouring could not remove because of insufficiently open raw-wool stock The fibers in a card sliver present a far better surface for effective cleansing than the stock has shown in any previous process

Backwashing is not always done directly after carding but may be done after one or two gillings, but always preceding combing, in the Bradford system. If the card sliver comes in balls, these are usually arranged on the floor, i e, twelve to thirty-two balls around the feed end of the backwasher. The ends are taken from the center of each ball and fed into the backwasher. Some manufacturers have a special creel on which the balls from the railway head are arranged on pins and unrolled. This has its disadvantages, however, because of "stop and start" and extra manipulation difficulties.

If the card sliver comes from the card in deep cans, ten to twenty cans are grouped behind the backwasher

Machinery for backwashing. There are two styles of machines used in the United States for backwashing All backwashing machines can be had with a minimum of one bowl up to a maximum of four bowls for the washing, and with either hot-air drying or can drying. Two-, three-, or four-bowl machines are also used in producing colored tops, whereas two- or three-bowl equipment is generally considered satisfactory for white card sliver in worsted spinning mills and in custom or commission combing plants

The first suds bowl has a pair of 5-inch-diameter copper feed rollers, and two pairs of 3½ inch-diameter copper or brass immersion rollers with weights for top rollers. There is also a 3½-inch-diameter single immersion roller and a 3-inch-diameter guide roller Another and later construction of the first backwash bowl is the substitution of brass-tube skeleton rollers in place of the plain immersion rollers and of a 16½-inch-diameter brass drum resting upon seven 3⅝-inch brass immersion rollers that are driven by frictional contact. The second suds bowl has two 3-inch-diameter copper guide rollers and two 6-inch-diameter immersion rollers Rugged pairs of steel squeeze rollers are securely housed and serve each bowl for the removal of excess water or liquor

The first bowl usually takes a solution of olive oil soap or olein soap and warm water. The soap should be neutral and develop a creamy lather at the nip of the squeeze rollers Alkalies are not ordinarily necessary and are not used A new supply of soap is added when this lather tends to reduce The second bowl is the rinsing bowl and contains only soft water at a temperature of 105° F (and not over 120° F) Some operators add a little ammonia and some a little blueing, if it is work that is done on commission Such backwashing improves the appearance of the slivers and noils as well as increases their market value The squeeze rollers remove the excess water, which runs back into the bowl, and the group of slivers are now subjected

to a drying process Generally, a stream of water is run into the second or higher bowl so that the overflow with the excess soap will flow down to the first or lower bowl Regular soap additions have to be made under these circumstances

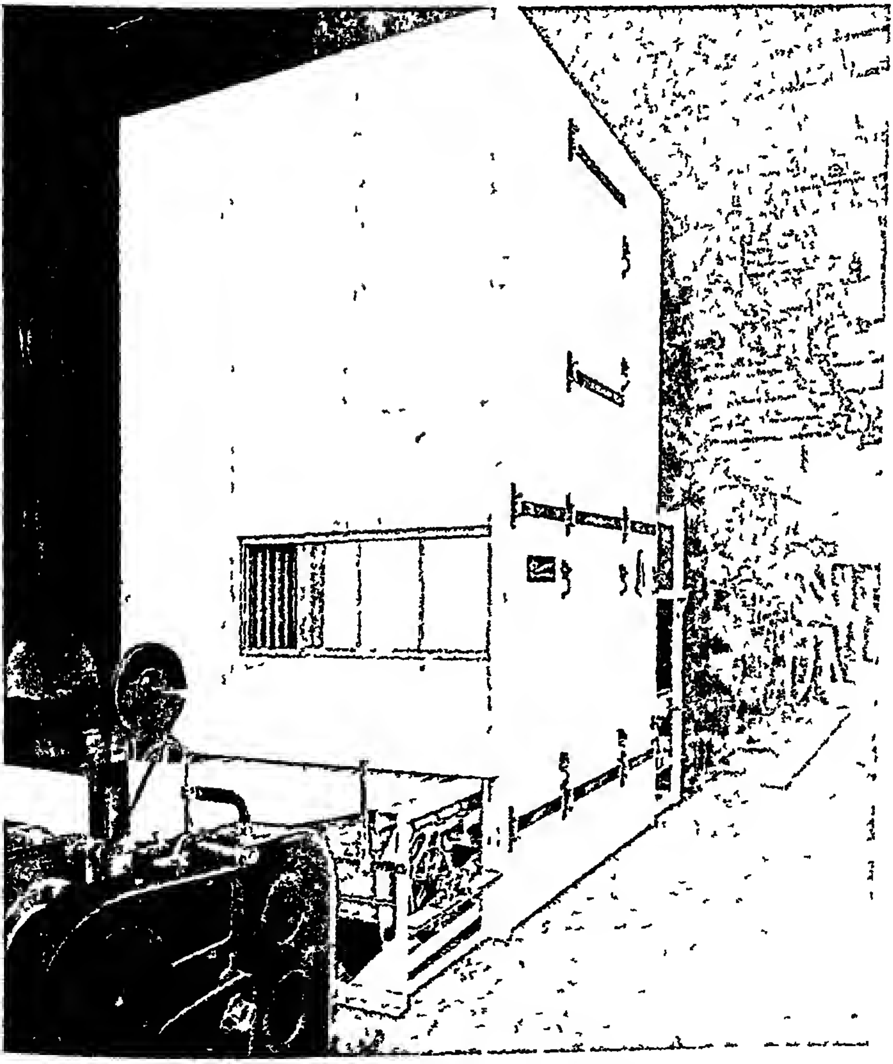

Fig 6 Hot-air dryer for backwashing (*Courtesy Proctor & Schwartz*)

Drying the slivers The group of continuous slivers (or tops) then passes into a dryer, of which there are two types, can dryers and hot-air dryers.

Hot-air dryers seem to be preferred in the United States because the slivers have no direct contact with hot metal surfaces Many of the older mills, of course, have can-dryer installations, some of which are encased in housings provided with glass windows, although others have no housing at all. There is a hot-air dryer that has three aprons and is housed in cast-iron construction, the sides and top of which are double-thickness steel, asbestos-insulated, and provided with removable panels and glass windows in the sides and top which permit a full view of all sections of its interior. The horizontal aprons, on which the sheet of slivers rests, consist of patented, spirally woven, wire cloth. By means of a sprocket chain drive the aprons pass the slivers three times the length of the dryer. Warm air, heated by steam coils, is circulated by two ball-bearing fans through and over the wool slivers. It is claimed that this hot-air system gives the wool a softer feel and better color and maintains greater strength in the wool. The sliver group is not under tension, hence there is no opportunity for the ends to break down. Even if they did, they would retain their relative position on the aprons and could be spliced before they enter the gill box, which is usually used after the dryer. This dryer can be used for drying both white and colored sliver, also vigoureux top, and can dry from 100 to 400 pounds per hour.

There is a backwash dryer (Fig. 6) that is a radical advancement in dryer design because it eliminates the old difficulty of speeding up the drying process to keep pace with the gill boxes. The drying time is materially reduced and amazing savings are made in floor space, steam and motive power. Added advantages claimed are increased capacity and perfect uniformity of dried sliver.

Oiling the slivers It is the feature of the English system that the wool is combed in oil. The addition of oil is made not only to facilitate the further processing of the wool fiber in the subsequent gilling and combing operations, but also to give particular properties, such as appearance and better handle to the finished top sliver. In the case of wool, about 3½ percent of suitable oil is added. The choice and preparation of such oils are discussed under the heading of oiling of the stock in Chapter 10 on woolen carding. The application of oil to the material is usually made at the feed end of the gill box attached to the backwashing machine.

One of the simplest oiling devices is a plain, smooth, metal roller, which is mounted in a trough of oil so that a portion of its circumference comes in contact with the emulsion This roller, slowly rotated by a belt, carries a thin film of oil on its surface upward and around until, by means of one or more little metal gutters, tin strips, or scrapers, the oil is conveyed by its own weight in droplets onto the wool running directly under them The amount of emulsion can be regulated by the number of these conductors employed Of course, a supply tank is provided also, which by means of a simple copper float or disk keeps the level in the oil trough always the same, ensuring absolute uniformity of oil supply to the passing wool There are other methods of supplying oil emulsions to the wool but this is the simplest device used extensively in American mills

Gilling or Preparing

The properly backwashed, dried, and oiled group of twelve to thirty-two slivers now enters a gill box connected directly to the dryer The gill box constitutes the third section of the machine and provides a means of delivering the slivers in a form suitable for future gilling and combing operations On the Bradford system, using long and crossbred wools, the slivers are combined into one and delivered into sliver cans rather than balls The word *preparing* means the preparation of the wool for the comb in a preparer or gill box

Principle of gilling In a gill box two important operations take place (1) a combing operation, when fine steel pins pierce the wool and comb it out, and (2) a straightening operation, when the front rollers draw the wool through the assembled faller pins The ratio of the speed with which the slivers enter the gill box, and that at which it is taken away in this operation, is called the "draft" This simply means that if for every inch of sliver entering the gill box, twelve inches are delivered from the gill box, it constitutes a draft of 12 The draft, of course, is divided into back draft and front draft, which will be explained later

The principle of the gill box as it is used in the Bradford system is best illustrated by Fig 7.

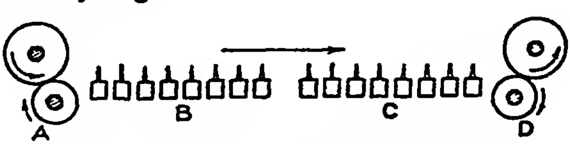

Fig 7 Principle of the gill box and fallers.

The sliver sheet enters feed roller *A* and, as it does, fallers *B* and *C*, which have one to three rows of strong steel pins inserted in them, come up into the slivers and move away in the direction of the arrow faster than the sliver, and hence subject the wool-fibers to a combing action The fallers travel along for about 6 inches and then drop into a lower level, to be returned to the feed end again One faller follows another and there may be as many as sixteen to twenty-four fallers working in such a gill box The slivers move forward in a horizontal plane and are finally gripped by the pair of delivery rollers, which deliver the sliver through a trumpet and calender rolls *D* into a sliver can, usually rectangular in shape.

While the fibers are held by the back roller, they receive more combing action than after they are released. While being held the fibers are combed by a set of progressively-forward-moving bars, with one row of vertical steel pins each working between them These bars are termed *fallers* and rise into the wool as soon as it comes from the back rollers The surface speed of these fallers is greater than that of the back rollers, and the wool is opened and straightened by the action of these pins and fallers At the same time there is a drafting as well as an intermixing of fibers and slivers This action continues for the distance between back and front rollers, until the front rollers grip the wool and draw it away from the slower moving pins, which then drop out of the wool and down and are then rapidly returned to the back roller A

The *ratch* or distance between back and front rollers (center to center) varies according to the length of the wool With long wools the distance may be 20 inches and with shorter-than-7-inch wool it may be only 10 to 12 inches The diameter of the pins, the length of the pins, and the rows and the spacing of the pins vary in such machines according to the stock On the first gill box they are large in diameter (5/32 to 5/64 inch) and long (3 to 1¼ inches) in a single row and set openly (three to six per inch) At any one time there are usually twelve to sixteen fallers operating in the upper layer of a machine and seven inoperative The material is delivered by the front rollers to a leather apron when a flat band is to be made for coiling into a metal or fiber can Or, if a round sliver is to be made the wool ribbon is delivered through a trumpet and a pair of calender rollers into a can The speed of the calender rollers is about 2 to 5 per cent higher than the delivery rollers to prevent the sliver from piling up around the guide plate and passing down in bunches

Types of drafts There are three drafts to be considered in a backwash gill box (for that matter, in any gill box) (1) back draft,

(2) front draft, and (3) total draft

The word *draft* is a common term in all textile work, wherever drawing of slivers or rovings is done In all gill boxes and drawing machines the front rollers move faster than the fallers and the fallers move faster than the back rollers The relation of the surface speed of the fallers to the surface speed of the back rollers is known as the *back draft* The relation of the surface speed of the front rollers to that of the fallers is known as the *front draft* The relation of the surface speed of the front rollers to that of the back rollers is known as the *total draft*

The relation of these drafts is carefully adjusted to the various stocks and differs with various gilling and drawing operations Some foremen consider that there are two general aspects of drafts, namely, (1) mechanical drafts, and (2) material drafts

The mechanical draft is the ratio of the surface speeds of the back and the front rollers The material draft is the fiber movement occurring in the machine and is expressed as the ratio of the length fed into the machine to the length delivered For instance, a back roller may have a surface speed of 100 inches per minute and the front roller a surface speed of 600 inches per minute, this would be mechanical draft Material drafts are expressed in weight of sliver, for instance, if a sliver weighing 12 ounces per running yard is fed into a backwash gill box with a draft of nine, the sliver issuing from the gill box would weigh 1 1/3 ounces per yard

In calculating mechanical draft, the gears and the rollers which affect it are generally divided into two groups

1 *Drivers or increasers,* which are those that when increased in size or number of teeth would give *more draft*

2 *Drivens or decreasers,* which are those that when increased in size or number of teeth would give *less draft*

Usually all "drivers" are multiplied together, and all "drivens" The drivers' product should then be divided by the drivens' product and the quotient obtained is the draft in that gill box A typical set of speeds is assumed to demonstrate the calculations

Surface speed of back rollers = 144 inches per minute
Surface speed of fallers = 144 inches per minute
Surface speed of front rollers = 864 inches per minute

With these assumed speeds, it is relatively simple to calculate the "front draft"

$$\text{Front draft} = \frac{\text{Surface speed of front rollers}}{\text{Surface speed of fallers}} = \frac{864}{144} = 6$$

Calculation of the "back draft" is as follows:

$$\text{Back draft} = \frac{\text{Surface speed of fallers}}{\text{Surface speed of back rollers}} = \frac{144}{144} = 1$$

The *total draft* of a backwash gill box, as explained before, would be the ratio of movement between the back and the front rollers, which may be expressed in this way:

$$\text{Total draft} = \frac{\text{Surface speed of front rolls}}{\text{Surface speed of back rolls}} = \frac{864}{144} = 6$$

The total draft can also be found by multiplying the back and fronts drafts, thus

$$6 \times 1 = 6 \text{ (total draft).}$$

If one is not familiar with the gear calculations and wishes to set up a total draft calculation, it would shape up as in the following calculation (which can be traced easily on any gill box):

Draft Gear		*Diam Front Roller*		*1st Large Stud Gear*		*2nd Large Stud Gear*		*Back Roller Gear*		*Front Roll Drive*
33	x	19/16	x	60	x	50	x	77	x	40
60	x	2½	x	19	x	40	x	19	x	28
Front roller Main gear		Diameter Back roller		Back shaft gear		First small stud gear		Second small stud gear		

Total draft = 6

These calculations, of course, can be utilized to calculate change gears and draft changes and to obtain a balanced production from any gill box and keep it in line with the production of the next machine and others A balanced production throughout a set of gill boxes necessitates such calculations and changes frequently If one box lags behind, the production of the whole set, range or assortment is delayed.

Fluted feed rollers and their calculation. The use of fluted front and back rollers requires some explanation because such rollers are extensively employed in worsted drawing in both the Bradford and French systems Smooth or round rollers were found ineffective and unsatisfactory because they allowed the wool fibers to pull through the nip of the rollers, no matter what pressure was given the top roller Too much roller pressure can not be employed because of resulting damage to wool fibers. Hence, to soften the "nip" and to be able to increase the pressure, the rollers were covered with leather in the first efforts to avoid such damage This was not sufficient.

however, when large numbers of heavy slivers were going through the machine Others utilized an endless leather apron running over top roller or bottom roller or both, as is often the case on delivery rollers of backwash gill boxes To hold these in position and prevent them from slipping on the smooth rolls, it became necessary to "flute" them The flutes are smooth valleys, cut horizontally or spirally across the roller's circumference. A single roller may have from four to six flutes in its circumference Such rollers are made of special steel that has been thoroughly casehardened Top and bottom rollers must be fluted the same way and fit perfectly, otherwise trouble will ensue through cutting or chafing of the wool fibers, particularly when running rapidly The fluting of the rollers was found to be the best method of handling wool on gill boxes, of obtaining the greatest parallelization of the long wool fibers, and of eliminating slippage in the feed or delivery roller nips Endless aprons can and are run especially between the front rollers because they run at a greater speed than the back rollers and have a thinner layer of woolen fibers between them The leather acts as a cushion and prevents the fibers from being cut, yet it grips the wool firmly and in this way the drawing effect of the rollers and the whole drafting process is increased

The preceding calculations for front, back and total drafts are affected when fluted rolls, especially in combination with leather aprons, are used There are many mathematical ways of calculating the output of fluted rollers, but they are not for the practical man because there are too many variables to be taken into consideration The most practical method for determining the output per revolution of all such rollers, whether or not a leather apron is employed, is to run a thin flat cloth or paper tape through the actual pressure of the rollers for *one complete revolution* of the bottom (or driven) roller of the pair For this purpose the roller or the gear attached to its shaft is marked with chalk, in order to be sure that one complete turn is given The amount of tape taken in by the rollers can then be measured in inches more accurately than it can be calculated These figures can then be used directly in the preceding equations in place of the calculated diameters of the rollers

Stop motion Many mills running on the Bradford system, where such gill boxes are extensively used, like to place uniform lengths of slivers into the cans or upon the balls For this purpose stop motions are employed, irrespective of how many heads a gill box has By a head is meant the number of cans or balls made on any gill box There are usually two heads to a backwash gill box, i e, two

balls or two cans in the delivery head. A knock-off and measuring motion of the "candlestick" type is generally employed It consists of a short upright shaft which receives its motion from the front roller by a single worm A change gear is placed on the top of this shaft, which engages with the worm At the bottom of this shaft is a base gear, which engages with a stop wheel The base gear has an indivisible number of teeth—usually twenty-nine—which prevents the same teeth from meeting until a whole cycle is completed The stop gear is fixed to a movable stud which is pushed to actuate the stop lever when two projecting pegs or catches that are located on the top of the base gear and the stop gear meet. The cans usually hold from 400 to 500 yards of gilled sliver. Fiber or tin cans are used, which usually measure 40 inches high and 12 inches in diameter. Fiber cans are lighter, cheaper, and very popular.

Further gilling operations. The backwash gilling is followed by two to four additional gilling operations very similar to that described The number depends on the condition of the carded sliver after backwashing Usually two more gillings are given as a preparation for the Bradford system of combing, which is usually carried on with a Noble or circular comb. The backwash gill boxes, or can gill boxes, are used for this operation. This additional gilling is necessary to put the sliver in the proper condition for combing and give it the desired weight. The process remains the same except for an increased number of pins per inch in the fallers, and the relative speeds and the ends up behind each machine

Doubling. Since the card sliver, yard after yard, is rarely very uniform in weight, due to grinding, stripping, or cleaning of the cards and occasional variations in the feeding of the card, depending on whether a hand feeder or automatic-weigh feeder is used, it becomes necessary in the two to four gilling processes preceding combing mechanically to even out this nonuniformity of sliver weights as far as is possible This is accomplished by feeding a number of slivers into gill boxes and combining them into one or two slivers as the case may be This process is known as "doubling". It also serves the purpose of further mixing the stock or wool fibers and of obtaining a greater distribution of the various lengths of fibers throughout the sliver.

To illustrate this, the backwash box may receive 12 ends or slivers if it is a *single*-head can or ball gill box, or 24 ends or slivers, if a *double*-head gill box. Suppose 12 slivers, each weighing 15 ounces per 10 yards or 1½ ounces per yard, are fed into a machine, the

feed would be 12 x 1 5 or 18 ounces per yard This would be drawn out to 15 ounces per 10 yards and, at the rate of 82 inches per minute of feed, would deliver 40 ounces for a production of 150 pounds per hour The delivery in ounces per 10 yards is obtained by dividing the feed in ounces per yard by the total draft, and multiplying by 10

$$\frac{60 \times 10}{36} = 16\ 6 \text{ ounces per 10 yards of delivery}$$

The inches per minute of feed is obtained by dividing the surface speed of the fallers by the back draft (see page 531).

$$\frac{144}{6} = 24 \text{ inches per minute of feed}$$

The more times the slivers are "doubled" the more uniform will be the sliver weight and the mixing of different slivers from several cards or even of different lots, if it is desired to amalgamate them The greater the number of doublings the better the mixing and the uniformity of sliver and final yarn, if no combing is done

After repeated doubling and gilling, depending on the resulting sliver product, the sliver is now prepared to go to the comb

3 Punch or Ball Winding

For the Noble comb it becomes necessary here to convert the slivers into balls, four slivers per ball The machine employed is called a "punch" and its principle is very simple Four slivers of the proper weight are fed through guides into the machine and wound side by side and under pressure upon a square spindle with circular disks attached to each end When the ball is large enough, one of the disks is moved out or away, permitting the ball to be removed Punch balls in preparation of combing weigh about 20 pounds each and there are eighteen needed to fill up a Noble comb, making a total of 360 pounds of wool for one charge Compactness of the ball is obtained by a pressure weight and lever, which compress the ball during winding Care must be taken that all four ends are always present and that no "slicing" is done when the balls fall apart into two or three pieces

The weight of the slivers differs with the type of wool being run and can vary from 14 ounces per 10 yards on fine short wools to 24 ounces per 10 yards for coarse and long wools

Several types of balling machines are in use, some even provide a speed reduction during winding, i.e, winding rapidly at first and then more slowly as the ball increases in size, so that the sliver will not be pulled too fast as the balls fill up Spindle removal or head removal is used for the doffing of the balls

BRADFORD WORSTED COMBING

Worsted combing has three distinct functions to perform:

1. To remove and separate the "short wool" fibers below a predetermined length.
2. To straighten and to make the retained long wool fibers lie as parallel as possible
3. To remove foreign impurities, such as burrs, straw, shives, kemps, neps, weak fibers, and dust

In worsted combing the long staples or fibers are retained and made into comb slivers and later into "worsted top", whereas the shorter, wiry fibers are rejected in a fibrous mass known commercially as "noil," which forms a raw material used in the manufacture of woolen yarns and piece goods

Worsted yarns are made from the long and straightened wool fibers obtained from the worsted combing process, irrespective of whether this wool is the long, coarse, lustrous and straight used in the Bradford system, or the short, fine and crimpy used in the French system It is combing that gives worsted yarn made on the Bradford system its straight, smooth, clean and uniform diameter and appearance as against the rough, bulky, and irregular diameter and appearance of woolen yarn.

Combs and Combing

Four types of combs Worsted combing can be done on various types of combs invented in the nineteenth century in the United States, England and France. Their selection and judicious use for various types of wools and hairs is a matter of great economic importance The choice depends largely on the type of wool to be combed. Here length, fiber diameter and amount of noil permissible are taken into careful consideration. The types of combs available for worsted combing are four in number.

1. Circular comb
2. Nip-motion comb
3. Rectilinear comb
4. Square-motion comb

They are also known by the names of their inventors the Noble or circular comb, the Lister or nip-motion comb, the Heilmann, French, or rectilinear comb, and the Holden or square-motion comb As far as the Bradford system in the United States is concerned, the only ones which come in for consideration are the circular or Noble comb, and the nip or Lister comb Of the two the Noble comb is the most common in the Bradford section of the American worsted industry and is the one which will be described here However, a comparison of the two latter combs will serve some purpose

The Noble comb is the most comprehensive machine of the worsted industry and can accommodate all qualities and a wide range of wool types Its production is greater than that of any other comb, and the quality of the noil and the top is usually entirely satisfactory

The nip or Lister comb can be used only on long wools and hairs and the principle of combing employed is most suitable with longer wools of rather loose nature Its action is almost human, easy and with a minimum of fiber breakage, yet the separation of long and short fibers is thorough The tops produced are the smoothest, with the fibers absolutely parallel and of excellent spinning capacity. The nip or Lister comb is used so little in the Bradford system in the United States that any further description is not considered essential

History of combs. The invention of these combs is of some interest to the people in the industry Hand combing continued to be practiced until about 1870 Hand-combed slivers were used for fifty years after open drawing and throstle spinning machines were introduced, which proves that combing was the most difficult problem to solve and mechanize, particularly so on wool Not until 1853 could a comb be used without individual attention The first comb was invented in 1790 by Dr Edmund Cartwright It was called the "Big Ben" and consisted of four hand combs placed on a drum Although it straightened out the fibers, the removal of the combed wool was exceedingly difficult Up to 1805, Dr Cartwright had evolved three models, all of which had some elements which are retained to a degree in our modern combs James Noble of Leeds in England invented the Noble or circular comb in 1805 and made further improvements on it in 1833 1835, and 1845 It represented more than forty-eight years of study and experimenting in the life of the inventor and was patented in 1853 The Heilmann comb, invented at Mulhouse (France) in 1846 was not originally a worsted comb Heilmann was a student in engineering and made this comb to win a prize of 5000 francs offered by an Alsace cotton manufacturer for the combing of

cotton A description of the Heilmann comb is given in the section on French worsted combing in this chapter

In 1849, Lister and Donisthorpe invented a comb In 1848 the square-motion comb was patented and by 1856 reached its present state of perfection

Principle of combing In all worsted combing there are five stages or steps

1 Feeding the wool to the comb
2 Preliminary combing
3 Final combing
4 Sliver formation
5 Noil removal

Nearly every type of comb has its own method of feeding the wool to the machine In the Noble comb "punched balls" of four slivers are used, the Lister comb takes the wool like a gill box does, and so forth The principle of preliminary combing is the same in every machine, but different ways are used to accomplish it A fringe of wool is prepared, comb pins, press knives, and steel clamps are used Combing is completed in nearly all cases by drawing-off rollers which seize the fibers and pull them out of the pins The sliver is made through the agency of drawing-off leathers which collect the fibers and pass them forward in dense formation Noil removal varies with each comb In the Noble and Lister combs, the long fibers are drawn away from the short ones The top is drawn off and the noil is left in the pins

Operation of the Noble Comb

This comb, first invented by James Noble of Leeds in 1853, took forty-eight years of development before a satisfactory machine was produced Improvements are still being made in the machine, which is still imported by American worsted (Bradford) yarn manufacturers It is the principal comb used in the Bradford system of making worsted yarns out of medium-to-long crossbred wools Its production is greater than any other comb and its scope is wider Labor costs are low because its operation requires little attention when supervised by a capable foreman The performance of the Noble comb has been greatly accelerated by a double-balanced dabbing brush, which increases the production about 20 per cent, and by the

adaptation of ball bearings to the circle carriage, which effect a great saving in the power required to operate the machine

Parts of the Noble comb The principal parts of the machine, explained by referring to Fig 8, are (1) The large, horizontal circle *a* with eight rows of vertical pins, the number per inch and diameter varying in each row, the fewest and the thickest being in the outside row (2) Two smaller inner circles *b b*, which operate within and on opposite sides of the large circle, with five rows of verticle pins. The inner row of pins is the coarsest and has the least number of pins per inch The outer row of pins comes very close to the inner edge of the large circle (3) Two high-speed dabbing brushes *c c* to drive the wool down into the pins of the large and

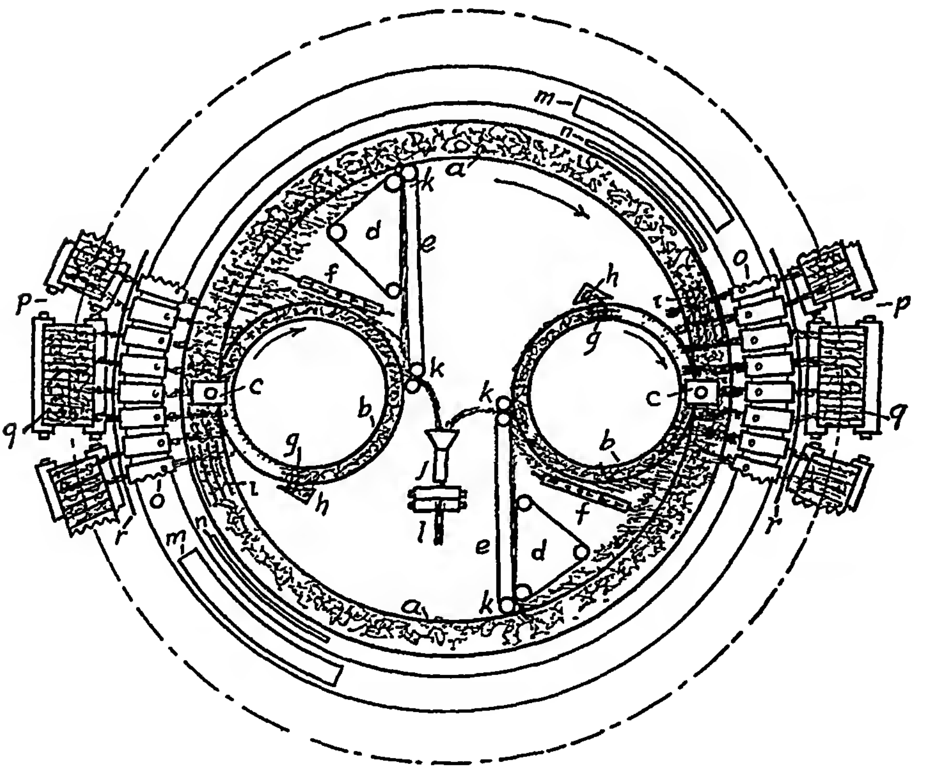

Fig 8 Principal parts of a Noble comb

the small circles at their point of convergence. (4) Four pairs of vertical drawing-off rollers, each lettered *k*, which serve to draw off the long fibers from each circle (5) Two star wheels or dividers *f f*, for flipping the extending fringe of wool fibers into the path of the drawing-off rollers and aprons *d* and *c* (6) Feed or trap boxes *o o*, one for each sliver (7) Cleaning knives *i*, noil knives *g*, and press knives *m* and *n*

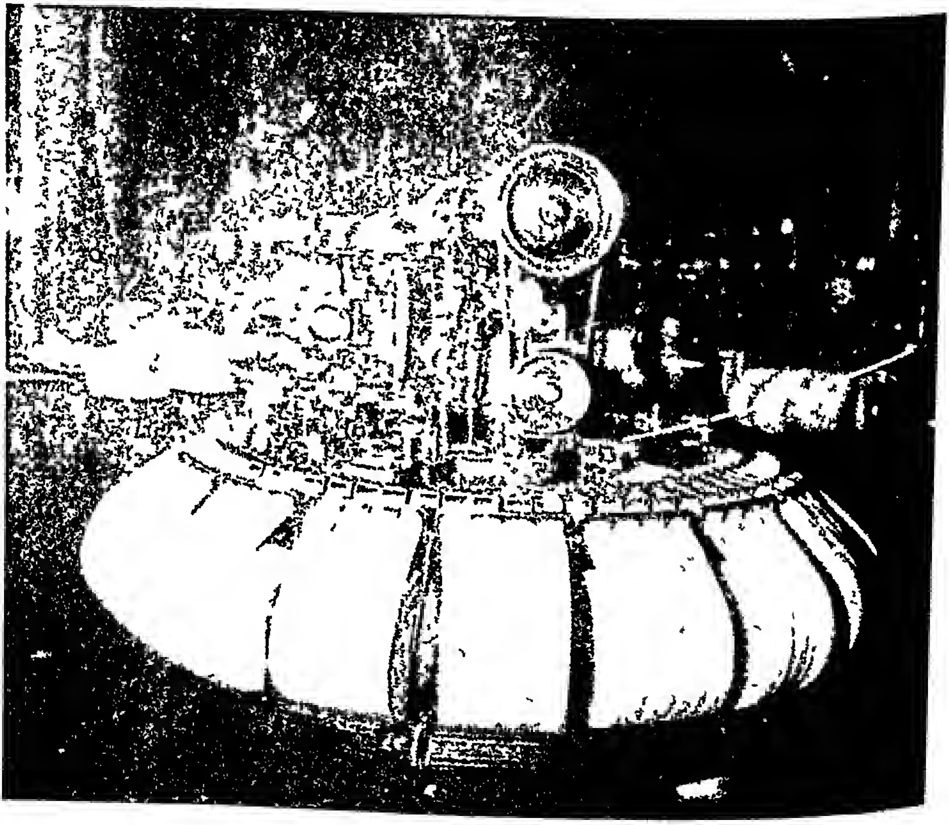

Fig 9 General view of a Noble comb

Combing procedure. The balls of wool *q* prepared in the punch box are placed in the revolving creel *p* in the rotating carriage, one ball in each trap, containing four slivers Each sliver is threaded through feed boxes or conductors *o* and is laid over both large and small circles at the point of convergence *c* The dabbing brush now descends and presses the wool into the pins of both circles. Separation of the material is effected through the slow but constant rotation of

the circles about their own axis as indicated in Fig 10 of a Noble comb in full operation

Thus, the long fibers are drawn by the circle that has the greatest hold upon them through the rows of pins of the opposite circle They protrude as a fringe on the inside of the large circle and on the outside of the small circles The star wheel *f* now flips the fringe of fibers, so that it points in the proper direction for withdrawal by the drawing-off rolls The short fibers or noils remain behind in the pins of the small circles only

The combed long fiber is drawn continuously at four points *k*, two at the large circle and one on each of the small circles The ends are united into two slivers (one on each side of the comb) and later combined at a center point, passed through a funnel or trimpet *j* and pair of calender rolls out of the comb and spiraled into a tall delivery can (see Fig 8)

The noil left in the pins of the small circles is removed by stationary, curved, and inclined knives *h*, set between each row of

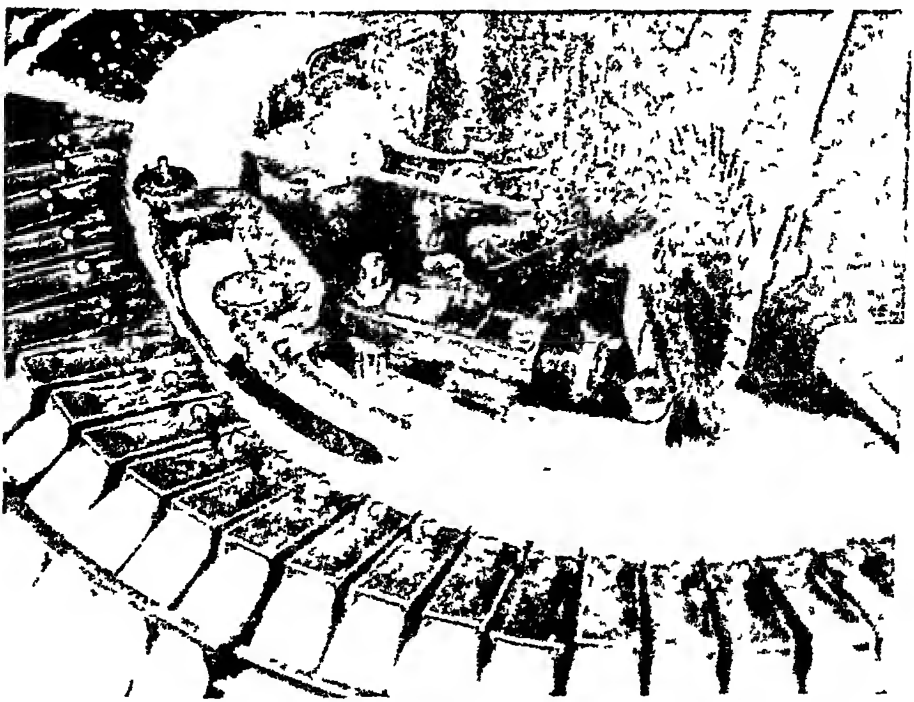

Fig 10 Close-up of a Noble comb in operation (*Photo by Leigh Irwin*)

pins Upon being pried to the top of the pins the noils fall over the edge of the circle into an inclined slide which leads to a noil can or receptacle The small circle is ready to be filled again when it reaches the point of contact with the large circle, where it again becomes charged with more uncombed wool sliver.

This completes the cycle of combing wool on the Noble comb The process goes on constantly and with very little attention The feeding of the comb is accomplished by running the material, the continuation of the sliver already in the pins of the main circle, under stationary press knives The press bars hold the stock in the pins of the large circle as the fore part of the feed boxes is raised The raising of the feed boxes, which are hinged at their backs, is accomplished by passing them over an inclined plane This pulls at the slivers on the punch ball and delivers a short length of more sliver Upon running clear of the press knives each end of sliver is lifted by stationary lifting knives (bars between the rows of pins on the large circle to the top of the pins) The sliver is straightened on a straightening plate prior to being laid over the moving large and small circles at the point of tangency The dabbing brushes now dab it down into the pins and the cycle is repeated.

Pinning details Pinning details are very important to the practical comber, who distinguishes the circles by the number of pins in the finest row, that is, a "26 circle" has 26 pins to the inch Small circles are pinned with finer pins The combination of large and small circles is usually referred to as 26/28 or 35/38 or 42/46, meaning, in the first instance, a large circle of 26 pins per inch with a small circle of 28 pins, etc Note the different combinations of circles that are used with different qualities of wools The secret of good combing is at this point It is best to have such circles made and repaired by experts only

Dabbing The dabbing of the wool into the pins is the most difficult and expensive part of the whole comb Many different methods have been tried, such as the single-cam dabbing brush, dabbing blades, rotary brushes, and air-blast dabbers Since the pins are moving, the wool slivers must be dabbed into the pins with one stroke or a sequence of quick strokes, which controls the speed with which the cylinders can be rotated Accurate setting of the brush is very important, because so much depends on it The bristles in a dabbing brush are made of Indian hog hair of best quality and should be lifted out when the comb is not running

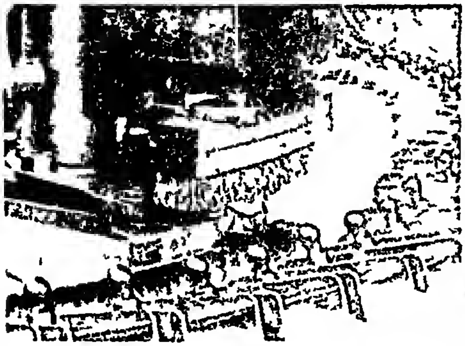

Fig 11

Fig 12

Fig 11 shows the general lay-out of the new method of dabbing including the angle of inclination of the small circle, the dabbing brush, the holding-down knife and the support knife The latter is discernable under the fringe in the small circle In this instance a circular brush is being used to assist the wool in entering the pins of the small circle.

Fig 12 shows the small circle cover plate and the path of the wool when it is assisted in entering the pins of the small circle, in this instance, by means of a circular brush The circular brush has been removed to show the wool in the pins

Fig 13 shows the path of the wool when it enters the pins of the small circle solely by reason of the latter being set at an angle The brush dabs into the large circle only

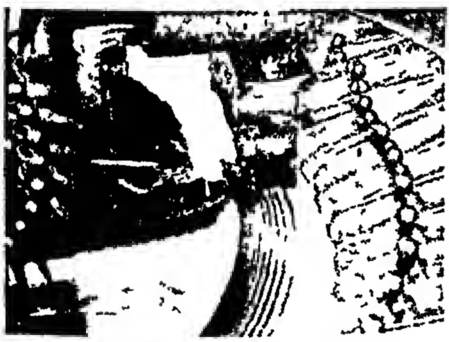

Fig 13

Figs 11, 12 and 13 Methods of dabbing wool in the Noble comb

To eliminate excessive wear at the heel of the dabbing brush on the Noble comb, a new method of dabbing has been invented by Griffin[3] The wear that takes place with the ordinary arrangement of circles is due to several causes, the four chief being:

1 The wool must be dabbed into the large and small circles simultaneously at the point where they are closest together, generally termed "the point of contact" This is obviously the point of densest pinning and, therefore, the most difficult place in which to dab

[3]Griffin T F, *J Textile Inst*, 35, T[illegible]

2 The wool must be dabbed into the pins to its full working depth in one dab of the brush

3 The brunt of the work of dabbing the wool into the pins is borne by the first few bristles in the brush.

4 During the time the brush is in contact with the pins, the latter are passing sideways through the bristles.

In the new method of dabbing, the first objection is overcome by inserting the wool into the pins in *two* stages: first into the large circle and, at a later stage, into the small circle The second objection is removed because it is no longer important where the wool first enters the pins of the large circle, since combing does not commence at that point It is thus possible to use a tapered brush that dabs lightly at the point where the wool first passes under the brush, and gradually increases the depth of dabbing until the point of contact is reached The third objection is removed by the fact that the work of dabbing the wool into the large circle to the full working depth is shared by a much larger area of the brush In the ordinary type of dabbing brush, the first half inch of brush does most of the work, whereas in this method the work is shared by several inches of the brush. The fourth objection is lessened because part of the brush is dispensed with

Drawing-off rollers The drawing-off rollers, which take the combed fringe of wool from the large and the small circles, are very important because the four pairs used vary in size for different circles The arc of contact is greater at the outside point and larger rollers are used The distance of the drawing-off rollers from the pins is important and has a direct effect on the noilage, or tearage, as it is called in Great Britain On fine merino wools a setting of 1/32 inch is customary, whereas long wools are given a setting of ¼ or ⅝ inch The small circle has a fringe made up of shorter fibers than those of the large circle The two are combined on reaching the funnel, where their separate identity is lost The drawing-off leathers, with which the delivery rolls are covered, have two main objects (1) to act as a cushion between the two fluted steel rollers, (2) to form the combed fibers into a sliver and convey it to the sliver funnel The apron is passed around a pressing roller and held in position by springs The outside leather wears out much sooner than the inside one, which has only the small circle fringe to draw off Thick leathers give best wear, but thin ones give better grip Suitable comb leathers should be about ⅛ inch thick for fine wools, ¼ to 15/16 inch thick for long wools.

Sliver removal. The sliver from each of the outside rollers is carried through the inside rollers, where the fibers are drawn off by the inside rollers and combined into one sliver each The two slivers are now combined at the sliver funnel, where sufficient false twist is inserted into both slivers to bring them across the comb to the coiler or delivery can "False" twist is a "temporary" twist, which is only inserted to hold the fibers together sufficiently to permit transfer or removal from a machine without breaking the continuity of the sliver movement A rotating funnel is on top of the coiler to remove the twist inserted by the comb funnel The sliver is coiled into a can instead of being balled, because coiled it can be more easily drawn out with little tension and friction or disentangling of the fibers Hence, in reality, a falst twist is again inserted

Temperature and humidity Moisture and heat have been found essential in combing wool The slivers should leave the backwash containing 25 to 28 per cent moisture, so by the time the wool leaves the comb there is 8 to 10 per cent moisture left It is very important that the comb be heated before it is started after a week end, in running it cold there is danger of damage to pins and leathers

The humidity in combing rooms requires attention if a satisfactory product is to result The manner in which moisture is best replaced is humidification by mechanical means Table 10 in Chapter 11 gives details of suitable temperatures and relative humidities for all processes in wool manufacturing For a temperature range of 75°-80° F, the recommended relative humidities for the card room are 60-70 percent and for the combing room, 65-75 percent

Production of Noble comb The production of a Noble comb depends mainly on the material being combed and the amount of noils being extracted With the average speed of the large circle at 4 r p m the average hourly productions range approximately from 40 pounds for merino wools to 70 pounds for low Crossbred wools The average tear or ratio of top to noil may run from 8-15 to 1 for crossbred wools and 8 to 1 and lower for 64s/70s merino wools

TOP GILLING OR TOP FINISHING

In the Bradford system, two further gillings are given before the commerical worsted top becomes a reality The functions of these two operations are:

1. To accomplish a thorough blending of all lengths of fibers, which the comb does not effect evenly

2 To continue the straightening and paralleling of the combed wool fiber

3 To condition the wool for the purpose of restoring the natural amount of moisture to the top.

4 To give the sliver a uniform weight, yard after yard

5 To wind it into a convenient-size ball of definite weight and length, for future handling or sale

This operation, known as top gilling or top finishing, is necessary to produce a commercial top of standard weight, length and condition

The slivers from the combs are quite uneven and nonuniform both in arrangement of different length fibers as well as in weight per yard If different combs are used, an opportunity exists here to amalgamate and blend the slivers. If the comb has dried out the wool, there is an opportunity afforded to add moisture or water If the comb sliver is very irregular, it can be "doubled" with others to produce the regular and even sliver so essential to the success of future drawing operations and to the final yarn itself The blending is accomplished by drafting and "doubling" slivers along the lines of previous gilling operations. This is accomplished generally in two chief gill boxes, known as the can gill box and the top gill box or, as they are sometimes called, first and second top-finisher boxes The first one is also called the conditioner box or gill, whereas the second is frequently referred to as the baller or top box.

Can gill box or conditioner This machine is very much the same as the backwash gill box or preparer gill box The pinning of the fallers is finer, the machine is lighter, and the delivery is usually into cans, but may also be in balls A measuring motion is present to ensure equal length delivery into the cans, so by weighing the cans, heavy and light slivers can be ascertained. The candlestick measuring device, which stops the machine when a certain yardage is delivered into the cans, is used again at this point

A large number of ends or slivers are put up at the conditioner box to obtain a thick sliver. Twenty-four to thirty ends are gilled-in when Botany wools are handled The draft of this box rarely exceeds five, hence a 1¼-ounce-per-10-yard sliver issues from the machine with twenty-eight ends up as a 7-ounce sliver per 10 yards, i e, $28 \times 1\ 25 \div 5 = 7$ ounces per 10 yards The thick sliver is desirable because it will pull out of the cans more easily and is less likely to fray

and break It also affords an opportunity to condition the slivers as well as to blend them thoroughly

Water evaporates very rapidly in nearly all operations in which fibers are exposed as an open sliver To compensate for the loss of water that has been mechanically held in the fiber, water is applied to the gilled sliver A fluted brass roller revolves in a tank of water kept at a constant level as the sliver passes over the top of it. This roller is usually placed between the calender roller and front rollers on the gill box The fluted roller revolves at a certain speed to deposit a definite amount of water on the sliver The speed of the roller controls the amount of moisture picked up by the broad slivers The drip method described under the previous section on backwashing can also be used when an emulsion of oil and water is preferred, 2 1/3 parts of oil and 16 parts of water to 81 2/3 parts of wool has been used to advantage on mohair sliver, for instance

The fallers in this gill box run three per inch for fine wools and two per inch for crossbred wools and are carried in double-thread screws made by the American Gill Screw Company The fallers have pins for 10 inches of their width and there are two rows of pins in each faller The pins per inch vary from 8 on long wools to 20 on fine Botany wools These fallers and their pins should be kept in perfect condition and repair This is best done by expert pin setters

Such a can gill or conditioner gill box is usually a single-head machine, meaning that it has only one set of delivery calender rollers They require about ¾ horsepower to operate and occupy a floor space of 4 feet 6 inches by 10 feet and are run at 300 to 325 r p m If colored slivers are run oil and water in an emulsion are applied as a conditioner to replace the oil removed in dyeing

2 *Top gill box or top baller* This machine produces commercial worsted top in the form of a ball of definite length and weight made on a balling head in place of the coiler of the machine just described In other respects the machine varies very little from the last gill box Only about six ends are put up at the rear (i e six cans or ends) and a draft of five is employed The result is a sliver of 4 to 5 ounces per 10 yards The standard weights of tops generally accepted in the trade are·

Fine Botany wool tops 64s to 56s, are 4 to 5 ounces per 10 yards
Crossbred wool tops, 50s to 40s, are 6 to 7 ounces per 10 yards
Long wool tops, 40s and below, are 8 to 9 ounces per 10 yards

Such tops become a saleable commodity and are subjected to regulations and conditions similar to other commodities

Characteristic top-making attachments are found on the second

top-finisher box, such as the straightening plate and the folder. When the sliver emerges from the front rollers it passes over a plate which has a series of bars which straighten it out and bring its uneven edges into conformity with the rest of the sliver. The folder turns the outer edges to cover one-quarter of the distance on each side, thus producing a top ball of a unique and neat appearance

The balling head puts the sliver into a traverse on the ball, equally across the width, which makes a solid ball that is flat at one end and solidly wound to stand transportation or storage As each top is produced at the top box, the operator in charge knocks out the tapered spindle upon which the ball of sliver has been wrapped and replaces the spindle between the guides, after which the stop motion is reset and the machine started again The top is weighed either on a spring balance or a pair of good scales, each ball being weighed separately, as a check on the sliver weight. A five-pound ball of top sliver weighing 4 ounces per 10 yards would have $5 \times 16 \times 10 \div 4 = 200$ yards per ball Any top that does not conform to the quality standards is rejected and passed back to be remade. Tops which pass the weight test are tagged with a ticket giving the number of the machine, the operator, and the lot The top is next wrapped separately in a piece of paper, cut to the exact size, and tied up with string or tape. If more than one quality is made, different colors of paper are used for quick identification of qualities or lots

Such finished top, whether used by the manufacturer himself or sold in the market to other spinners, is usually stored in cellars or moist storerooms until the wool has had a chance to age Tops must be kept in moist, dark storage for at least one week before they are used to make worsted yarn. For testing tops for regain and other factors see Chapter 23.

FRENCH WORSTED COMBING

In the French system in the United States, the rectilinear or Heilmann comb is preferred to the Noble or Holden combs It is generally called the French or Continental comb and was originally invented for cotton. The term *rectilinear comb* comes from the fact that it is a straight-line comb as compared to Cartwright's and Noble's circular combs The machine is known for making good slivers of very short, fine wools and is the more comprehensive comb of the worsted industry. It can comb wools which are far too short for any other comb

Although a Noble comb has a greater production, a French comb occupies less than one-quarter of the floor space occupied by the former, and requires only one-fifth the horsepower to operate. Whereas one operator can easily supervise two combs of the Noble type, one operator can tend four to six French combs with ease The French comb is sometimes termed an intermittent comb, and the Noble comb a continuous comb The French comb not only combs very short Botany wools, but handles longer wools quite satisfactorily, hence it is indeed the most versatile comb in existence The original rectilinear comb was invented by Heilmann of Alsace-Lorraine in 1845 The French comb is built primarily in Europe by N Schlumberger & Cie, Delette-Gruen, and the Alsacian Machine Works in Mulhouse, France and in England by Prince-Smith and Stells, Ltd

Principle of the French Comb

The wool is prepared and fed to the comb in the form of laps or groups of slivers Laps are generally preferred because they produce better feeding of the fibers into the comb These pass through a pair of feed rolls and pass by a feeding gill (*r* of Fig 14, left) into the nipper jaws Z_2 The jaws Z_2 hold the fringe of sliver while a a circular plate comb *k* combs it out The circular comb *k* as shown is covered with eighteen needle bars for about one-third of its circumference Each needle bar has steel pins of ¼ inch length, varying in density from sixteen per inch in the first row to almost sixty per inch in the last row In front of the circle and on movable arms are the drawing-off rollers, which move forward in the direction shown in the upper right of Fig 14, and seize the combed fringe of wool at the free end The nipper jaws Z_2 are then opened as shown at the bottom right and an intersecting or top comb *f* descends into the fringe as yet held by the drawing-off rollers The process is completed when the drawing-off rollers draw away the fringe of wool which must pass through the pins of the intersecting or top comb *f*, removing any short fiber held in the other end of the fringe The movable drawing-off rollers lay the tufts of combed wool, overlapping each other, onto a delivery leather, so that a tufted sliver results This tufted sliver is compressed by calender rolls and finally delivered and coiled continuously into a can The noil is removed from the circular comb and the top comb, in the former case by a revolving brush *b* from which it is removed by a wire brush *d*, and an oscillating comb *h* finally drops it in the noil box or receptacle In the latter case (the

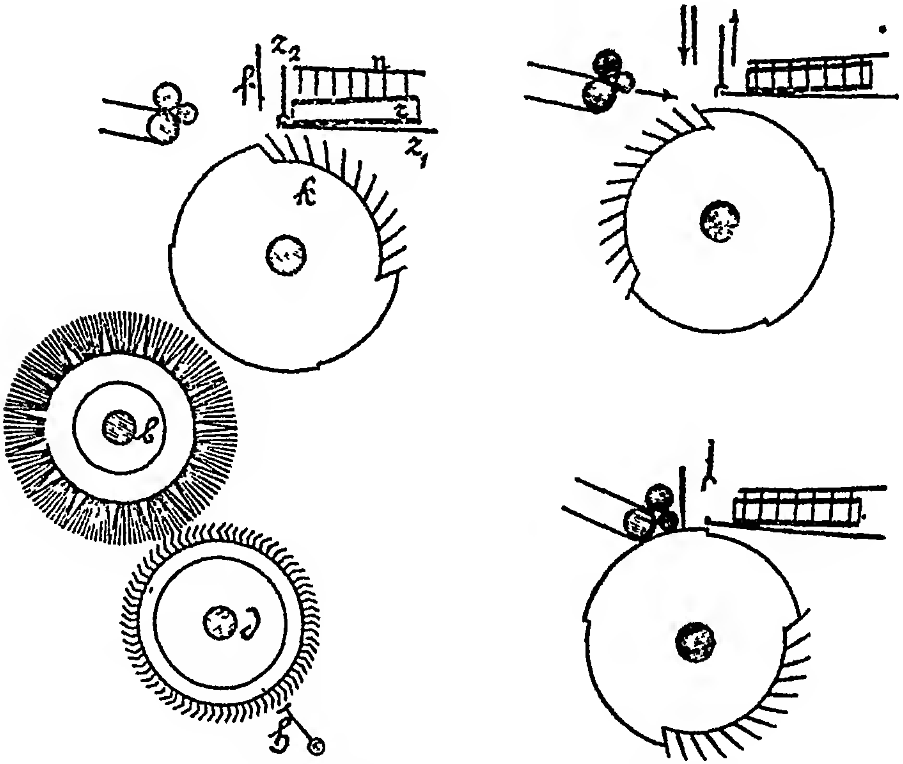

Fig 14 Details of a French comb (*Preu*)

top comb), the noil is removed by a blade clearer The three successive stages of the operation, i e nip, comb, detaching, are illustrated by the left, top right, and bottom right diagrams of Fig. 14

Principal Motions

Contrary to the circular comb, the principal motions of the French comb are intermittent except for the noil-removal and the can-rotating mechanisms The intermittent motions during combing in the order of their recurrence are

1 Feeding mechanism motion
2 Reed comb motion
3 Nipper motion
4 Drawing-off motion
5 Sliver formation motion.

The comb is made in two widths: the narrow model about 14 inches and the wide model about 19 inches. When combing fine wools the amount fed into a rectilinear comb is usually as follows:

Narrow model: 36 ozs. per five yards, made up of 24 slivers each weighing one and one-half ozs. per five yards, or 18 slivers each weighing two ozs. per five yards. Continental practice favours total weight of slivers fed in 200-220 grs. per meter.

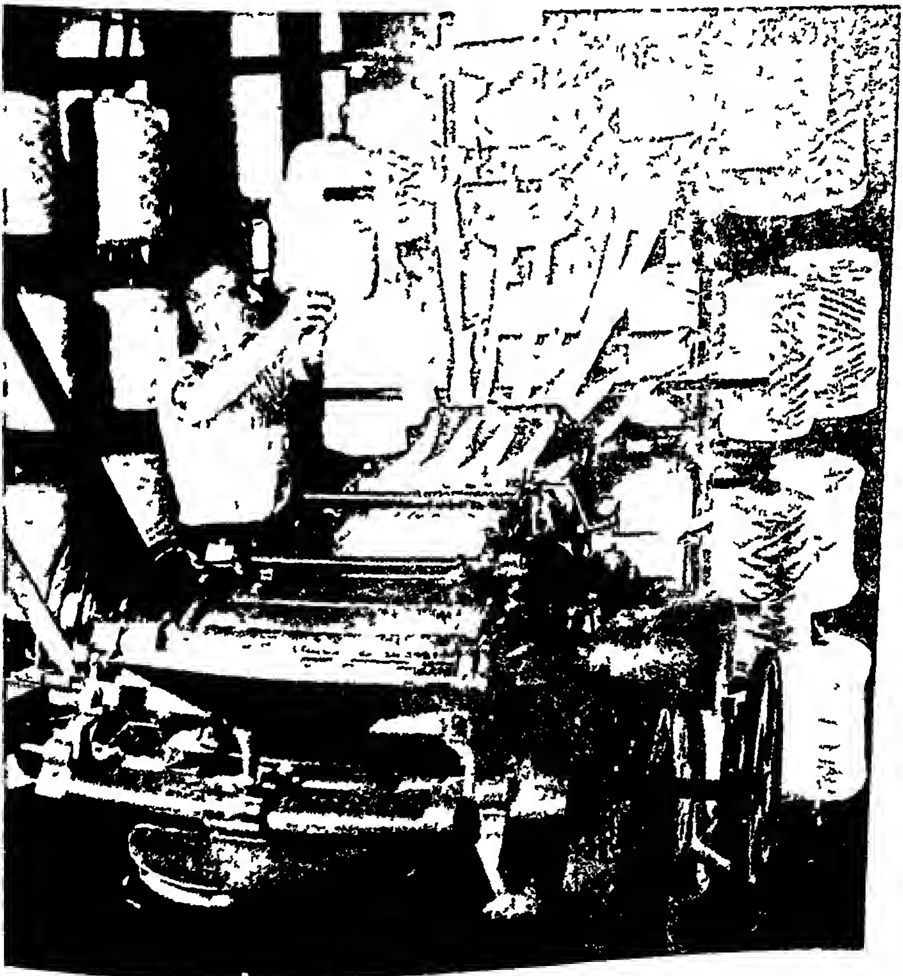

Fig. 15. The French comb. *(Courtesy Arlington Mills.)*

Wide model: 48 ozs. per 5 yards, made up of 32 slivers each weighing 1½ ozs per 5 yards, or 24 slivers each weighing 2 ozs per 5 yards Continental practice favours total weight of slivers fed in 270-300 grs /meter They are laid side by side until they make a flat feed by a pair of driven-feed rollers. These rollers have round helicoidal flutes and are geared to give ¼ to ⅜ inch variations of feed at a time They pass through two brass guides (one stationary and the other following the motion of the feed gill) which guide the lap into a feed grate The amount of sliver fed into a French comb is governed by the feed ratchet wheel, which can be changed to accommodate different rates of feeding.

The top and the bottom feed plates, called *grid bars*, are grooved and slotted. The reed or front comb consists of eight rows of pins placed in a brass section The feeding mechanism is largely determined by the amount of noil to be taken out

The nipper or nipper jaws, with a stationary axis, usually has two oscillating plates or jaws, the upper jaw is grooved and has an overhanging lip which completely covers the lower jaw The lower jaw has a triangular flange which fits into the upper jaw and thus holds the fringe. To secure a perfect grip of the fibers throughout its free width, a special lever is placed under the lower nipper plate which prevents the lower edge from touching the pins of the circular comb

The Heilmann comb has a barrel-shaped cylinder, with pins set in rows projecting outward and pointing forward in the direction of rotation It is 6 inches in diameter and is provided with eighteen rows of pins fixed in slots The pinned portion of the circular comb is in two sections, the first which holds the first nine rows of pins is usually constant The second section of pins is made interchangeable and can be altered for each different type of wool used

The initial combing is brought about by the combination of movements between the nipper jaws and the circular comb The nipper jaws hold a fringe of fibers between them, while the circular comb brings a series of rows of pins through the fringe When the initial combing action is finished, the nipper jaws open and the fringe of fibers is seized by the drawing-off rollers, which are brought forward by the carriage A top comb or intersector, combs that part of the fringe previously held between the nipper jaws for the initial combing This comb descends as soon as the fringe is gripped by the drawing-off rollers (Fig 14)

The drawing-off rolls are covered with a comber leather, which is about 21 inches wide and about 25 inches long inside (wide model

comb). They receive a forward and backward motion at each nip for the splicing together of the wool tufts The drawing-off rolls are assisted by a sword and a counter-sword, the former to complete the drawing of the long fibers and the latter to present the "tuft' to the drawing-off rolls

The combed wool is converted into sliver by pressure rollers following the leathers, by an oscillating funnel or trumpet, and by the calender rollers, which pass the sliver into a revolving upright can of 12 or 14 inches diameter and 31½ inches height

The French comb will not deliver a satisfactory sliver when the wool is dry Combing should be done in a room of about 75 per cent relative humidity The distance between the nipper and the drawing rollers is adjustable by a single patented gauge, permitting adjustment from ⅝ to 2⅜ inches The normal speed of the French comb is 275 r p m with a pulley of 11 13/16 by 2¾ inches, representing 100 drawings The wide French comb with a thirty-two-bobbin-creel occupies a space only 1¾ yards by 3½ yards

A special blade known as the *burring* blade is employed in the French comb for the removal of burrs. It consists of a knife which runs up the face of the comb circle and dabs between the seventeenth and eighteenth row of pins The motion of this blade causes the wool fibers as they are held by the jaws to be brought to the bottom of the pins, leaving the burrs at the top of the pins, which are then swept by the noil brush It can be used preferably on very fine, short and burry wools, but has been used on qualities below 50s Ramie and rayon staple fiber can be combed on the French comb

Production on the French Comb. The production of the rectilinear comb is dependent on three items

1 From a mechanical point of view by the nips or dabs per minute, usually about 100
2 By the amount of pick of the ratchet operated feed rollers
3 By the weight per unit length of the sheet of wool fed in If the sheet is thicker, the tuft drawn will naturally be thicker, hence a higher production

It is therefore difficult to give exact productions, which also depend upon the type of wool and perfection of the carding, with any degree of accuracy; however, the average production on fine wools may be taken as follows.

Narrow model comb	. 12 to 14 lbs	per hour, average 13 lbs
Wide model comb.	. . 16 to 20 lbs	per hour, average 18 lbs

On coarser wools the above productions are considerably increased

Only enough short fiber is ordinarily removed in combing to ensure a satisfactory top Naturally, the more short fiber is present in any quality of wool, the more noil will be removed and the greater the loss in the amount of long fiber obtained This is reflected in the price of the top Broken fibers and neps depreciate the value of a top as well as the presence of dirt, particles of burr, and bad color Combing to a large extent controls the quality of tops and must be adjusted to give the desired top according to what the market or the spinner deems adequate and satisfactory.

Noils

Noils constitute the short or broken long wool fibers removed in the combing process Noils are, therefore, a valuable commercial commodity, subject to price fluctuations and segregated according to source, cleanliness and length

Noils are usually sold by the worsted yarn manufacturer to woolen yarn spinners, who employ them as an admixture in the production of fine woolen yarns The cleaner they are, the greater their length and the finer the quality of wool from which they originate, the higher the price they bring in the open market, all other things being equal

The price of Bradford noils from Noble combs generally is two-thirds of the price of the scoured wool used, whereas the French noil is fifty-five per cent of the scoured wool price (See Chap 6).

Amount and type of noils The amount of noils obtained in combing is largely dependent on the lengths of wool handled as well as the type of combs used In Table 1 is shown the average noilage produced on French combs These figures are based on the actual mill production of several million pounds of Australian as well as domestic wools In Table 2 is given as an example, the noilage of three types of wools, based on the scoured yield, showing clearly the influence that length plays

If dyed or bleached tops are recombed the noilage produced depends entirely on how the tops were treated during processing and usually varies from 2 to 5 per cent, rarely more If felting of the wool has occurred during dyeing the noilage will be greater.

TABLE 1 RELATIONSHIP BETWEEN FINENESS, LENGTH AND AVERAGE TOP AND NOILS YIELD IN FRENCH COMBING (BASIS—15% REGAIN)

Origin	*Grade of Top*	*Av length in inches*	*Scd yield* (in %)*	*Top yield (in %)*	*Noils yield (in %)*	*Tear***
Australia	90s	2 20	62 8	50 0	10 1	5 1
Australia	80s	2 50	64 1	54 1	7 3	7 4 1
Australia	70s	2 70	65 4	56 3	6 7	8 4 1
Australia	64s	2 85	66 2	58 0	5 7	10 2 1
Australia	62s	3 10	68 0	59 7	4 5	13 3 1
Australia	60s	3 20	69 1	61 5	4 0	15 4 1
Texas						
12 months	70s	2 10	44 4	34 8	6 9	5 0.1
	642	2 25	42 7	33 0	6 6	5 0 1
6 months	64s	1 85	43 8	30 9	9 4	3 3 1
Territory	58s	3 15	42 4	36 5	3 0	12 2 1

* The scoured yield includes the top and noil yields plus carding and combing wastes
**Tear is weight ratio between top and noil

Statistics for yield in scouring various Australian combing wools

	Coefficient of Correlation
Fineness Length	+0 9854
Length Top Yield	+0 9903
Length Noils	—0 9923
Fineness Scoured Yield	+0 9944

TABLE 2 NOILAGE OF THREE TYPES OF WOOLS BASED ON SCOURED YIELD

Grade	*Wool type*	*Length in inches*	*Noilage in percent*
64's	6 months Texas	1.85	21
64's	12 months Texas	2 25	15
64's	Austral Fleece	2 85	9

TABLE 3 NUMBER OF WORSTED CARDS AND COMBS IN THE UNITED STATES

Year	*Cards sets (by cylinder size)* 48 in	54 in	60 in	Total	*Worsted combs* Noble	French	Total
1943	354	526	1022	1902	1653	[illegible]	[illegible]
1947			...	..	1672	[illegible]	[illegible]

Chapter 13

ENGLISH AND FRENCH WORSTED DRAWING

WORSTED DRAWING constitutes a series of operations used in both the French and the Bradford systems The worsted top sliver is converted into a roving which is so small that it can be spun conveniently into a fine, even yarn on the spinning machine

In all drawing operations, the parallelization of the wool fibers is continued Drafting is also practiced to the extent that the sliver is gradually reduced to a point where it becomes small enough that it can be spun readily into a single worsted yarn Doubling is also practiced extensively to equalize the irregularities in sliver thickness or weights which may be produced and that may lead to uneven yarn All drawing processes, irrespective of the system used, depend on two or more pairs of drafting rolls and a packaging of the reduced sliver

Systems of Drawing

In the field of drawing there are distinctions made between various systems which were developed more or less simultaneously in several European countries Three systems of drawing are generally recognized in the United States.

1. Open drawing, known as the Bradford or English system
2. Cone drawing
3. Porcupine drawing, known as the French or Continental system

1 Open drawing Open drawing is generally used in the United States on long and coarse luster and crossbred wools It renders a strong, level, but hairy or fuzzy worsted yarn Oiled tops are used and twist is employed in the final stages of reducing and roving It is the oldest system of drawing worsted top.

2 Cone drawing Cone drawing is used on long, fine wools which are converted into rovings from oiled tops Cone drawing results in less waste and a more uniform yarn than the open system, with much less strain on the roving and yarn Cone-drawn yarn is relatively

more expensive than the open drawn, everything else being equal It is used to produce fine worsted yarns for hosiery and dress goods

3 *Porcupine drawing* Porcupine drawing, also known as French or Continental drawing (from first being used on the Continent), is extensively used in the United States on short and fine merino wools It is employed in the production of very fine and expensive hosiery and dress goods Worsted yarns of the best quality are obtained by this system. It creates yarns of fuller and softer handle from dry-combed tops, which excel in elastic properties Generally, dry or unoiled tops of 1¼- to 4-inches staple length are used for French drawing False twist and rubbing is used to hold the light roving together Novelty blends are successfully handled by this system

4 *Anglo-Continental drawing.* Another system of drawing has been developed in England It is known as Anglo-Continental drawing, on which it is possible to draw oiled tops on the French or porcupine system of drawing It is patented by Prince-Smith & Stells, Ltd, of Great Britain, and now obviates the old distinction that oiled tops cannot be run on the French system (For a detailed explanation, see the last section of this chapter)

Number of operations In all of the drawing processes, the number of steps required varies according to the size of worsted yarn that is to be spun from any given top, and the quality of the wool employed On the open, cone, or porcupine system fine, uncolored wools will require nine individual operations, and colored or top-dyed stock eleven or even twelve operations

The reason for the additional processes is the blending of mixed colors or the necessity for very level results in solid shades For crossbred wools of medium length seven individual drawing operations are necessary, whereas long wools, mohair, etc, require only six operations

The selection of good tops is vital in all systems Unless tops measure up to requirements, it will be difficult and costly to spin a strong, elastic, and level yarn, no matter what precautions are taken in any system Tops, as explained before, are judged according to (1) fineness of wool diameter, (2) length of fiber, (3) proportion of long and short fibers, (4) uniformity of length and fineness, (5) defects such as neps, slubs, and burrs and, finally, (6) sliver evenness Other considerations are the amount of oil in the wool, the age of the top, and the color and regain of the top Dry-combed tops are used in the French system, whereas oil-combed tops are used in the open or English and conedrawing systems

1. Open Drawing: Bradford or English System

This is the oldest system of drawing worsted top and was the first to be introduced into America. Originally the Bradford system was designed to deal only with luster and other long English wools Today, the system can accommodate long, short, and medium wools Mohair, alpaca, goat's hair, and human hair, as well as the longer types of rayon staple are also extensively processed on this system, either alone or in mixtures with wools. The very fine and short merino and crossbred wools are still handled to better advantage by the French system

The Bradford system operates with oil-combed tops, and oil is added in some of the gilling operations, which renders the ultimate yarn elegantly smooth, and less liable to become charged with electricity.

Sequence of machines Drawing machinery is usually laid out in sets depending on the type of wool handled constantly or grouped for each type of wool that is to be handled, or an average set of machines that can handle a certain range of wools is employed.

Anywhere from five to nine operations are required to reduce the top slivers to the necessary thickness and uniformity of a roving suitable to spin a satisfactory yarn. Each set is carefully planned and laid out to accommodate the drafts and doublings necessary for the desired roving at the minimum cost and maximum economy of materials and production Generally, two gilling operations are used on the top sliver and these are followed by two or three drawing operations and then completed by finishing, reducing, and roving processes When heavy rovings or yarns are made, one or two of the last operations are omitted An extra gilling operation can be added advantageously to a set when fine wools are to be worked or when different materials or colors are to be blended.

In order to acquaint the student with the names and character of these machines, two common sets for different types of wools are given in Table 1 for comparison and to illustrate typical layouts used by American mills

The examples given on Table 1 illustrate only the two extremes in layouts for Bradford drawing, namely, long, coarse wools and fine cross-bred or Botany wools A comparison of the two drawing sets shows at once that fewer operations are required on long, coarse wools, namely, six processes (i e., two of gilling, three of drawing, and one of roving), whereas eight processes are necessary on the fine and short wools, namely, two or three of gilling, five of drawing, and one of roving The reason for these additional operations will become

evident as drawing is discussed in more detail The first step in all cases is the open gilling, on which two types of machines are employed in the English system.

TABLE 1 TYPICAL LAYOUTS FOR BRADFORD DRAWING SETS

Details	*Long, Coarse Wools*	*Botany Tops, Fine Crossbred*
Production per 48 hr.	4,500 lb	5000 lb
Count spun	1/6s	28s-40s
Roving 40 yd	20 drams	3-4 drams
1st gilling	Double-head can (1)	Double-head int can gill (2)
2nd gilling		2 spindle int can gill (2)
3rd gilling	2 spindle gill box (1)	6 spindle drawg box (1)
1st drawing	4 spindle drawing (1)	8 spindle drawg weigh box (1)
2nd drawing	6 spindle weigh box (1)	8 spindle drawg finishers (3)
3rd drawing	8 spindle finisher (2)	24 spindle dandy finisher (2)
4th drawing		32 spindle dandy reducer (6)
Roving	28 spindle rover (3)	36 spindle dandy rover (12)
Spinning	Flyer frame	Cap and ring frame

Open gilling The function of the open gilling is (1) to open the fibers of the top and facilitate drawing, (2) to permit and accomplish blending of various qualities, colors, and mixtures, and (3) to deliver an uniform end of a precalculated weight to conform to a regular drawing plan

For the first gill box, the top balls are placed on a creel holding twelve tops, which have positively driven, revolving tin or wooden rollers Some manufacturers use an unballing machine which unwinds the top and delivers the sliver free from twist into a can which is used at the first gill box. There are usually two or three of such gill boxes, which are classified into the following types:

1. Single-head can gill box
2. Double-head can gill box
3. Spindle gill box

The first and second types are of the same general construction and are similar to the gill boxes described under gilling except that they are constructed on a finer scale The double-head can gill box merely has double the delivery capacity, and delivers two separate slivers in two separate cans, whereas the single-head delivers only one sliver into one can. The details of finer construction are immediately apparent from Table 2, which gives the details for Botany and long wools

Can gill boxes This type of gill box was first invented in 1826 by William K Westley of England These gill boxes are often referred to as "bed boxes" From Table 2 it can be observed that the feed rolls are different in size, namely, a larger diameter feed roll is needed for

TABLE 2 DETAILS OF THE CAN GILL BOX

Details	*Short Botany*	*Long Wools*
Bottom delivery roll diameter	2 in.	3 in.
Top delivery roll diameter	2½ in	4 in.
Bottom feed roll diameter	3 in.	3 in
Top feed roll diameter	3½ in.	3½ in
Number of fallers	18	24
Length of fallers	18¼ in.	18¼ in
Pins per inch	16	9
Type of screw	Double	Single
Pitch of thread	⅜ in	⅝ in.
Speed of fallers	320	220
Wire gauge	18s	14s
Set over	4 in.	5 in

long wools than for short Botany wools The feed rolls are larger than the delivery rolls in both types of wools There are more fallers in the gill box for long wools than there are for the short wools. The type of screw propelling the fallers is double for short Botany wools and single for long, coarse wools and hairs. The pins are set in two rows per faller. The back pins are about ⅛ inch longer than the front The distance from the first pin to the last is known as the "set over," which is wider for long wools than for Botany wools Double-head gill boxes have fallers with two sections of pins. Feed and delivery rolls in gill boxes are made of steel provided with milled flutes The bottom rolls are positively driven and the top rolls ride in the flutes of the bottom rolls, held in position by strong springs

Drafting. The reduction of the diameter of a sliver is known as "drafting" and the ratio of drafting is the "draft" Usually the draft is held the same as the length of the wool fibers

Drafting is done between the feed rolls and the fallers, known as "back draft," and between the fallers and the delivery rolls, known as "front draft" The total draft is the ratio of the length delivered in to the length fed over a period of time The back draft usually does not exceed 1½ to 1, because the fibers will break when a greater draft exists.

Difference of opinions exists as to whether drafts in drawing should be (1) equal, (2) random, or (3) progressive Most people favor progressive drafts, which increase with each drawing operation. With equal drafts, the doublings are adjusted to meet the weight of sliver—as doublings are reduced, drafts increase Random drafts are chosen to suit each machine and its conditions

Doublings vary with the system of drawing In open or cone drawing sets, they are five ends up in gilling. Table 3 gives an idea of doublings, drafts, and weights of sliver for various wools

TABLE 3 DRAFTING DETAILS OF THE FIRST CAN GILL BOX

	Doublings	*Draft*	*Weight-Drams per 40 Yd*
Fine Botany wools	5	5	256
Medium wools	5	6	320
Long wools	6	7	439

The effective draft is found by dividing the total draft by the doublings. In a can gill box it is

$$\frac{\text{Draft}}{\text{Doublings}} = \frac{6}{5} = 1\ 2 \text{ (medium wools)}$$

The distance between the feed rolls and delivery rolls is known as the "ratch" It is measured from the nip of the feed rolls to the nip of the delivery rolls This distance is usually 1 inch above the fiber length, but there are other factors which are taken into consideration here, namely, thickness of slivers and quality of wool Thick slivers require a wider ratch than thin ones

In this process of preliminary gilling, two to three machines are needed With merino wools (60s to 80s quality) three gillings, and with crossbred wool (40s to 58s quality) usually two gillings are employed, the same is used for long wools

Spindle gill boxes The third type of gill box used in a set of open drawing is the spindle gill box It consists of feed rolls, delivery rolls, and fallers, but the sliver issued is wound onto wooden spools or bobbins by a "flyer" instead of into a metal or fiber can Here is where the transformation of a sliver into a "slubbing" takes place It enters the spindle gill box as a sliver and is delivered as a "slubbing" onto a spool, because it imparts a small amount of twist into the sliver Hence the difference between "slubbing" and "sliver" is that the sliver contains no twist or, in some cases, only "false" twist, whereas the "slubbing" does contain twist All other details are exactly the same

Twist The twist is imparted because the reduction of the sliver now makes it necessary It is imparted by a device known as a flyer, shown in Fig 1 The amount of twist should be sufficient to make the slubbing strong enough to unwind at the next operation and should at no time interfere with the proper drawing of the slubbing Too much twist will result in "twits" and plucking of fibers and the slubbing Insufficient twist causes the roving to drag, which results in uneven places The amount of twist cannot be properly calculated and is primarily guided by the strength of the slubbing Merino wools (short) usually have more twist per inch than crossbred or luster

wools At best the twist is very small, usually less than one turn per inch of slubbing It depends a great deal on the length and uniformity in length and fineness of the wool fiber The amount of oil or emulsion and the natural cohesive qualities of the wool also play an important part

Flyer and Bobbin In Fig 1 the arrangement of spindle *A*, flyer *C*, bobbin *E*, and slubbing *F* is shown The twist is imparted to the slubbing *F* in the spindle gill box by the flyer *C* The sliver *F* passes from the front or delivery rolls through a hole *G* in the top of the flyer *C* and then through a ring *B* at the top of the leg *C*, then one or two turns around the leg *C*, down to flyer hole *D* onto the bobbin *E* The entire flyer fits on top of the spindle *A* at *H*, so it turns with the spindle, which is usually driven from the bottom The twist that goes into the slubbing is governed by the speed of the spindle (which is the speed of the flyer) and by the amount of slubbing delivered by the front rolls per minute The bobbin rests loosely upon the lifter plate, which has an up-and-down movement in order to effect the proper winding-on of the slubbing onto the bobbin barrel, as it drags or lags behind because of its weight The faster the sliver is delivered the less twist will be put in, the flyer speed remaining the same.

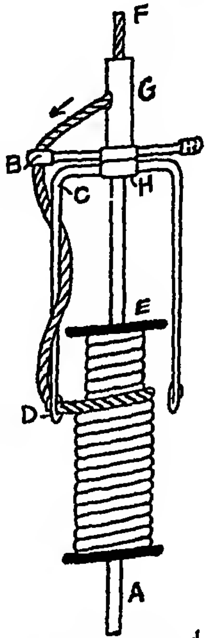

Fig 1 Flyer and bobbin detail

Drag Since the bobbins are not driven, a certain amount of drag must be given, drag is given by leather or felt washers used under the bobbin where it rests on the lifter plate. Too much drag strains the slubbing, which may result in breaking or uneven pulling Too little drag causes softly wound bobbins which are hard to unwind Of course, the drag increases as the bobbin gains in weight Constant adjustment is necessary to maintain an even drag throughout the filling of a bobbin, or in changing from one stock to another Long hairs and wools are difficult to regulate The wraps around the flyer leg can be changed to lessen or increase the drag

Ratch. The front draw rolls are usually stationary, but the back or feed rolls can be adjusted to the length of the stock The intermediate or carrier rolls merely act to hold the sliver in position No carrier rolls are used for very coarse, long wools The ratch is the

distance between the nip of the feed and the delivery rolls, and must be greater than the longest wool fiber in the stock "The ratch should be one less than the draft"—is a rule sometimes quoted but one not tenable for various reasons (1) Longer ratches should be given in the early gilling processes to prevent fiber breakage (2) "Oil"-combed tops require longer ratches than "dry"-combed tops (3) Ratches are generally shortened as the drawing progresses (4) The greater the slubbing twist the longer the ratch (5) Predominance of long fiber in the stock requires a longer ratch and vice versa

It is claimed that fiber breakage is largely caused by improper ratching in gilling and drawing The best rule here is "Practical experience and testing prevent fiber breakage"

Lifter motion. In open drawing and beginning with the spindle gill box, a lifter motion is employed It lifts the bobbins up and down on the rotating flyer spindle in order to wind the slubbing in uniform layers on the bobbin barrel At the end of each layer or one "traverse," as it is called in the United States, the lifter is reversed by the action of a mangle and peg wheel A slow traverse is to be preferred to a fast one

Open drawing machines Spindle gilling is now followed by three to five drawing frames, which are built the same as the spindle gill boxes The pin fallers are now discarded and smaller machine dimensions prevail as the slubbing advances Smaller bobbins, rollers, carriers, and tumblers correspond to decreased pitch as the roving becomes finer Open drawing on the English system performs several important functions

1. Doubling of slubbings
2. Reducing of slubbings
3. Insertion of twist.
4. Packaging or winding-on

Doubling is still carried on by mixing and combining several ends at the back of these machines The draft now exceeds the doublings in order to reduce the weight of the slubbing gradually but consistently, and to continue to mix the stock

Twist serves the purpose of giving added strength to the continually reducing slubbing, and is increased as needed Bobbins are used for packaging of the slubbing and are reduced in size as the slubbing reduces Drag winds the material on the bobbins

Drawing boxes are made in different constructions, by various builders, and often according to specifications to suit particular conditions, materials, and production setups They vary from two to eighteen spindles, which are driven by leather belts The low front

or delivery rolls consist of fluted cast-iron bosses shrunk onto steel arbors, while the top rolls may be iron or wood covered with leather, felt, or cork composition. These two lines of carrier rolls are made of special steel, not fluted, and the top tumblers are made of hard wood The back or feed rolls consist of four rows of rolls placed one above the other to secure an adequate nip They consist of cast-iron bosses shrunk on to a steel arbor, the row is fluted

All spindles and flyers are made of high-grade steel and receive special or local hardening to withstand rubbing of the slubbing A

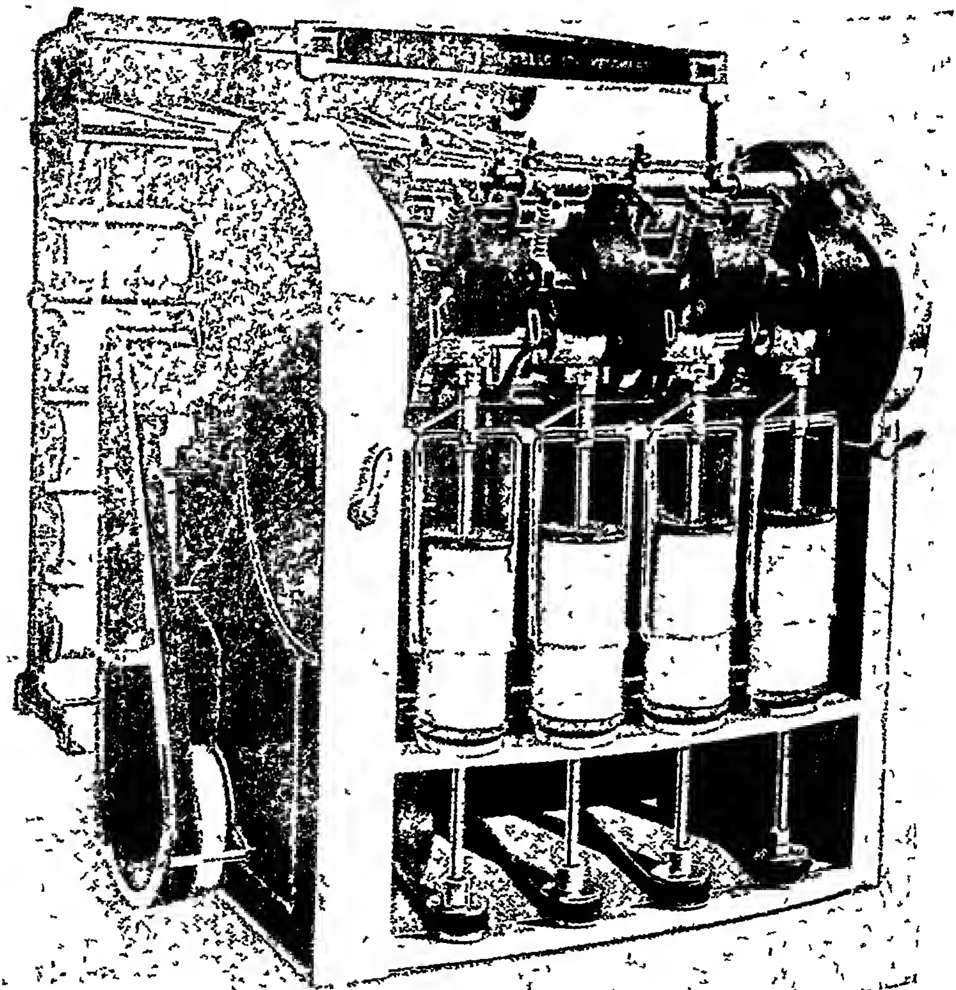

Fig 2 Four-spindle weigh box by Prince-Smith & Stells

new type of safety spindletop obviates any risk of damage caused by a lap forcing the top spindle to hoop out of the guide bracket A candle stick knock-off motion is provided to stop each machine automatically when a precalculated length of slubbing has been delivered Two types of creels are furnished by the builders, the swing creel and the stand creel

Table 4 gives an idea of the construction details and a comparison of how the machines differ in makeup It should be noted that the

TABLE 4 CONSTRUCTION DETAILS OF OPEN DRAWING FRAMES

Items	*4 Spindle Drawing*	*4 Spindle Weigh*	*6 Spindle Finisher*	*30 Spindle Rover*
Bottom del rolls diam (in)	6	6	6	5¾
Top del. rolls diam (in)	11½	11½	11½	9
Bottom feed rolls diam (in.)	3½	2½	2½	2½
Carriers, top (in.)	1¾	1¾	1¾	1½
Carriers, bottom (in.)	1¾	1¾	1¾	1½
Pitch of spindles (in)	12⅜	12⅜	10¼	6
Spindle speed (r p m)*	160	180	230	1000
Size of bobbin (in.)*	14 x 7	14 x 7	12 x 6	6 x 2½
Weight of bobbin (oz)*	64	50	38	5
Capacity of bobbin (lb)*	12	9	8	1
Doublings*	5	5	4	2
Draft*	6	8	8 5	10

*Will vary, of course, with stock run

TABLE 5 SEQUENCE IN OPEN DRAWING PROCESSES

	Fine Botany Wools	*Medium Wools*	*Long Wools*
1	Can gill box	Can gill box	Can gill box
2	Spindle gill box	Spindle gill box	Spindle gill box
3	1st drawing box	1st drawing box	1st drawing box
4	2nd drawing box	2nd drawing box	Weigh box
5	3rd drawing box	—	—
6	1st finisher	1st finisher	1st finisher
7	2nd finisher	—	—
8	Reducer	Reducer	Rover
9	Rover	Rover	—

DOUBLINGS AND DRAFTS

	Fine Botany Wools		*Medium Wools*		*Long Wools*	
	Doublings	*Draft*	*Doublings*	*Draft*	*Doublings*	*Draft*
1	5	5	5	6	6	7
2	5	5 3	4	6	5	7
3	4	5 5	4	6	5	7 7
4	4	5 75	4	6 5	5	8
5	4	5 75	3	7	4	8 5
6	3	6	3	7 5	2	10
7	3	6	2	7 5	—	—
8	2	6 5	—	—	—	—
9	2	6 5	—	—	—	—

spindle speed constantly increases (i e, from 160 to 1000 r.p m,) doublings gradually decrease, and drafts increase The size of the slubber bobbins decreases as the slubbing decreases in size A typical four-spindle weigh box with horizontal stand creel is illustrated in Fig 2, which shows the arrangement of the parts of this box quite well The other machines are similar in construction

The general setup or sequence of open-drawing processes on various wools is given in Table 5

These tabulations give a good idea of what machines are necessary, the doublings and drafts that are employed in the various grades of wools on the open system of drawing with oiled tops, and when twist is employed.

Reducer boxes The reducers in a set of open-drawing machines are similar to drawing boxes and finishers, but are built very light and run at much higher speed as can be seen from Table 4 The fine reducers are known as "dandy rovers" The number of operations or machines required here varies from one to three according to the weight of roving demanded Since these machines carry the greatest load and involve the largest capital of the whole set of drawing frames, it is natural that attempts are often made to increase the production of these machines, and thereby to reduce the operating costs and capital investment

Reducers, rovers, and dandy rovers are all machines of similar construction, light in weight, and built up to fifty spindles to suit individual requirements The spindles are driven by band or tape, which is cheaper than the belt drives used on open drawing boxes The spindles are set as close as posssible to the delivery rolls, which necessitates a movable flyer and spindle Drawing box and finisher spindle are supported at the top by a bracket and collar, whereas reducer and rover spindles are not supported at the top An "Eclipse" high-speed spindle (Fig. 3) manufactured by Prince-Smith & Stells, Ltd, can be installed in all old finishers, reducers, and roving frames On dandy machines, flyer speeds up to 2,400 r p m can be attained At such speed it becomes necessary to steady the spindle at the top with a top support which consists of ball-bearings enclosed in a special sleeve, the periphery of which is serrated. This outer sleeve is supported by an open bracket attached to the angle beam of the machine, and a locking spring is fixed to this bracket, the open end of which assumes a flexible contact with the serrated sleeve for the purpose of holding stationary the outer race of the ball bearing The unique design not only provides a perfect angular bearing when in running position

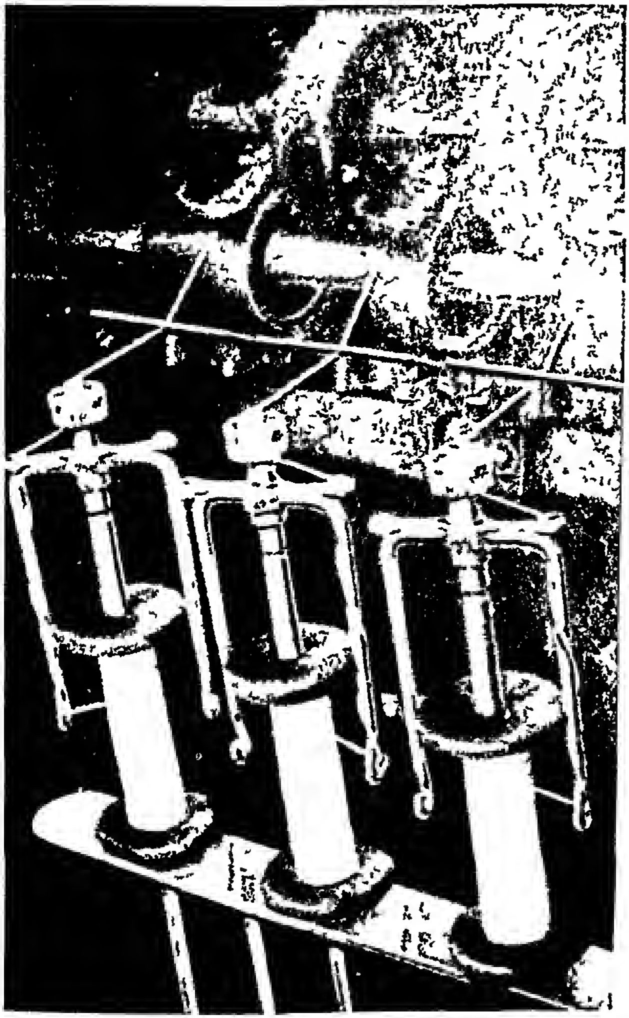

Fig 3 "Eclipse" spindle in position for doffing

but it allows the spindles to be swiveled outward for doffing in the usual manner, and back again into the running position without any additional movement for the operator, the release and relocking into running position being of an entirely automatic nature

The last machines in the open drawing set are the rovers or roving frames The last or fine roving machine is known as the "dandy," and is used if more than one roving operation is needed The bobbins used in these machines are very small, being 6 by 3½ inches, and weigh about 5 ounces each and hold about 1 pound of roving These machines usually have two ends up and produce by suitable drafts the exact weight of roving needed by the spinner to turn out the particular size of worsted yarn

Rovings for worsted spinning on the Bradford system are required to be regular in thickness and free from slubs, neps, and knots Stains of grease, dirt, dust, or oil should be prevented as much as possible.

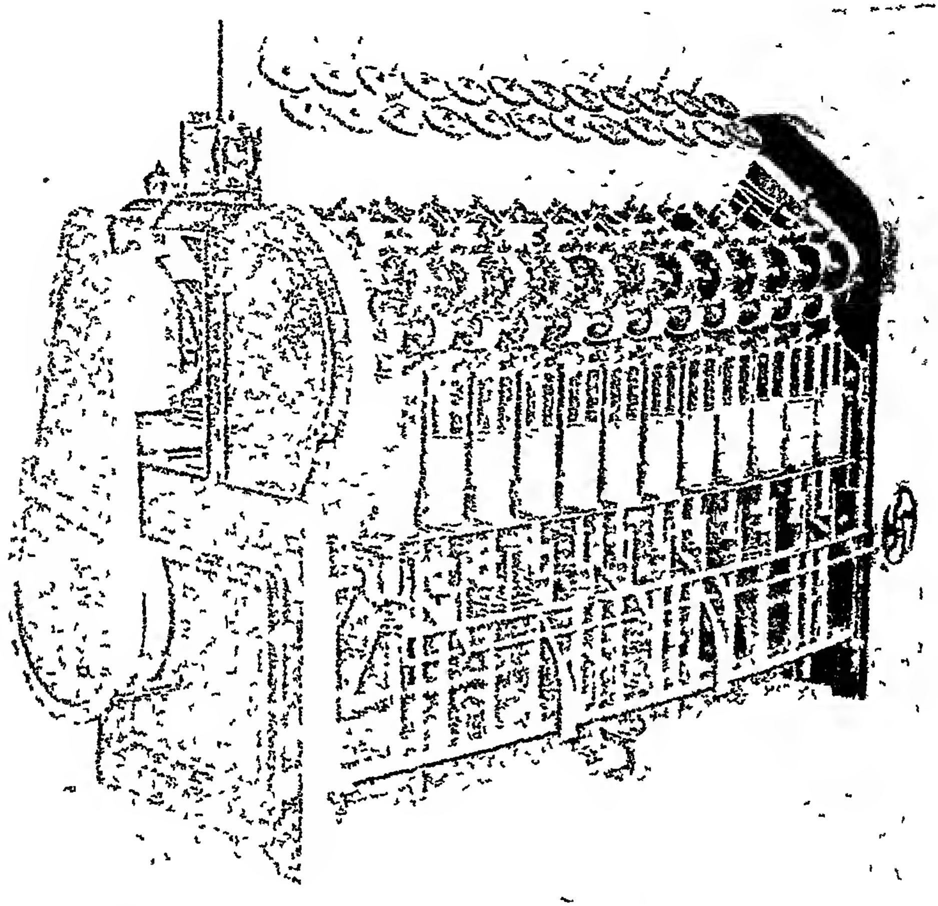

Fig 4 Modern dandy spindle rover by Prince-Smith & Stells.

Ring rovers. In late years ring rovers have been developed, or rather revived, when high speeds and increased productions have been needed, particularly in the United States The ring rovers permit spindle speeds up to 3000 r p m on worsted roving. It becomes necessary to use more twist on the ring rovers and the roving is not as smooth. However, very satisfactory results have been obtained on fine-quality wool rovings The greatest objection to them is the variation in twist as the bobbins increase in diameter. For instance, twist may vary as much as 85 per cent between the inner and outer layers of the roving.

The ring rover is a space saver and increases production. It is claimed that with the same number of square yards space the pro-

duction that is obtained is nearly doubled Another authority claims that the production of a ring averages at least 80 percent more than the regular flyer type Table 6 gives spindle speeds, bobbin size, traveler, and dram roving

TABLE 6 DETAILS OF RING ROVING FRAMES

Spindle Speed	*Size of Bobbin*	*Number of Travelers*	*Dram Roving*
3,400	6" x 3"	21	1 6
3,400	6" x 3"	19	1 9
2,400	7" x 4"	20	1 9
3,400	6" x 3"	18	2 3
2,400	7" x 4"	19	2 4
3,400	6" x 3"	17	2 5
3,400	6" x 3"	16	3 5
3,400	6" x 3"	14	4 0
2,400	7" x 4"	16	7

Drawing calculations There are many calculations pertaining to drafts, weights, doublings, and yarn sizes The student should realize that a good set of drawing has to be carefully planned through the various operations of gilling, drawing, and roving, the stages directly preceding the spinning operation Also, that a fine yarn requires a relatively lighter-weight roving and more operations of drawing and reducing than a coarse or heavy worsted yarn

Rovings and slubbings are calculated on the basis of drams per 40 yards, whereas gilled slivers up to tops are based on ounces per 5 yards The most important calculation in the drawing department of a Bradford-system yarn mill is the laying out of the whole system of drafts, doublings, and slubbing weights

To illustrate the method of laying out it is necessary to assume a certain set of machines for coarse, long wools as follows

1 One double-head can gill box
2 One two-spindle gill box
3 One four-spindle drawing box
4 One six-spindle weigh box
5 Three six-spindle finishers
6 Four thirty-spindle rovers

It is now necessary to determine what weight top in drams per 40 yards is required to make a 10-dram roving ready to spin If the equal draft principle is employed and a draft of 9 decided on, it now becomes necessary to decide on the "doublings" or ends up at each machine Suppose they were as follows

1. 6 ends up, draft of 9
2. 6 ends up, draft of 9
3. 5 ends up, draft of 9
4. 5 ends up, draft of 9.
5. 4 ends up, draft of 9
6. 2 ends up, draft of 9.

It is now an easy matter to ascertain the weight of the top per 40 yards, knowing the roving weight wanted, or vice versa, by using the following rule:

Multiply the weight by the drafts and divide by the number of doublings.

This means the following setup equation, solved for the weight of top required, based on 40 yards in drams:

$$\frac{10 \times 9 \times 9 \times 9 \times 9 \times 9 \times 9}{6 \times 6 \times 5 \times 5 \times 4 \times 2} = 738.1 \text{ drams per 40 yards top}$$

When the weight of the roving is required, the weight of the top is multiplied by the doublings and divided by the drafts, as indicated in the equation

$$\frac{738.1 \times 6 \times 6 \times 5 \times 5 \times 4 \times 2}{9 \times 9 \times 9 \times 9 \times 9 \times 9} = \text{10-dram roving}$$

The weight at each machine can be ascertained by taking each draft and doubling singly, thus:

$$\frac{738.1 \times 6}{9} = 492.0 \text{ drams per 40 yards (first operation)}$$

If the drafts are irregular or progressive, the same procedure is followed, substituting the draft in each operation in place of each one of the above 9s

2. Cone Drawing

The introduction of cone drawing to the worsted industry took place many years after open drawing was well established Cone drawing really came from the cotton industry, where it was used extensively before it was introduced into the worsted trade about 1905 It is and will continue to be of interest to the majority of spinners of fine worsted yarns by the Bradford system, especially to those who handle the shorter and weaker wools, or the wools that can be spun into finer counts than coarse and long wools Hind has drawn an interesting comparison between open drawing and cone drawing, which is given as Table 7 and clearly summarizes the advantages and disadvantages of the two drawing systems Cone drawing is preferred in the United States because of its greater production.

TABLE 7

COMPARISON OF OPEN DRAWING AND CONE DRAWING

Open Drawing	*Cone Drawing*
Friction drag	Mechanical winding-on
Smaller bobbins	Larger bobbins
More doffing	Less doffing
Uniform length per layer	Increasing length per layer
More twist required	Less twist required
Band-driven spindles	Wheel-driven spindles
Single end per head	Two ends per head
More floor space.	Less floor space.
More operators	Fewer operators
More piecings	Fewer piecings

Source Rearranged from Hind, J R, *Worsted Drawing and Spinning* Ernest Benn Ltd 1936

The main difference between open drawing and cone drawing is that in cone drawing the slubbing is wound onto the bobbin by a positive drive The bobbin in open drawing is loose on the spindle and dragged around by the slubbing Winding-on is accomplished by the lagging of the bobbin Because of its weight, which increases as it fills up, the friction drag increases as the bobbin fills and may cause severence or pull on the slubbing Hence more twist in the slubbing to withstand this increasing drag is necessary The lifter plate also moves up and down the traverse at the same speed at all times, whether the bobbin is full or empty.

Cone drawing, on the other hand, winds the slubbing on the bobbin without friction drag, because the bobbin is positively driven and is entirely independent of the spindle and flyer The speed of the bobbin is varied at each pick of the lifter motion, and the tension of the slubbing remains constant throughout the whole period of filling the bobbin The spindle and flyer are also driven positively, which ensures that the twist is both accurate and uniform throughout the final roving This is particularly important on fine rovings and generally results in fuller and more even roving In cone drawing it is only necessary to insert sufficient twist to control its passage from the delivery rolls to the spindle top and the twist is less than that required in open drawing For these reasons, larger bobbins may be employed, such as 8 by 4 inches on roving frames, even on the most delicate rovings

The only drawback to cone drawing is the more intricate and expensive cone mechanism, which necessitates large units and machines that are not advantageous on small lots However, it is claimed that the mechanism, once understood, is easy to adjust and gives less trouble Variations are less likely to arise than in open drawing In

other respects such as drafts, doublings, and number of machines or operations, the cone system is the same as the open system

The cone system is introduced to a set of drawing at any operation, but there are three standard types of arrangements

1. Full cone set including spindle gill box.
2. Open gill boxes and cone machinery for remainder.
3. Open gill and drawing boxes followed by cone finishing, reducing, and roving frames

The full set is very uncommon and modern conditions, particularly in American mills, favor the third alternative set

The cone system is carried out by means of a pair of cones and a differential motion, which is exceedingly difficult to describe without elaborate diagrams and lengthy descriptions It will, therefore, not be described here since suitable books on the subject are available from England

3 Porcupine Drawing · French or Continental System

This system of drawing is also known in the United States as the French or Continental system It is not to be confused with the Anglo-Continental drawing system, which is described in Section 4 of this

Fig. 5. Typical French drawing room in the New Jersey Worsted Mills, Garfield, N J

chapter The French system was introduced first in England, in 1851, and did not come to the United States until the late part of the nineteenth century It is particularly adapted for short wools, the staples of which range from 1¼ to 4¼ inches, although longer wools have been handled successfully on this system The name *Porcupine* is associated with French drawing because brass porcupine rollers, studded with fine steel pins, are employed between the front and the back drawing rolls, these rollers take the place of faller pins in drawing and the carrier rolls in the slubbing and the roving of the English system

French and English systems compared Generally speaking, there are more processes in the French system Whereas twist is employed in the English system, no twist or only "false" twist is utilized in the French system There are more doublings and shorter drafts in the French system Smaller rolls are employed because of the shorter wools used Porcupine rolls control the fibers during drafting A comparison of the two systems is best studied by Table 8 which summarizes the advantages and disadvantages of both systems

TABLE 8 COMPARISON OF ENGLISH DRAWING AND FRENCH DRAWING

Open Drawing	*French Drawing*
Fiber control by twist	Fiber control without twist
Lack of mechanical drafting control	Porcupine control
Drafting better with oil	Drafting without oil
High humidity unnecessary	High humidification necessary
Single-meche bobbins	Double-meche bobbins
More doublings	Less doublings
Drafts as fiber length	•
Slow reduction of sliver	Generally quick reduction of sliver

and wools of similar character as well as blends of cotton and wool and rayon staple fiber are being carried out with success under the French system. The system is primarily characterized by the use of dry-combed tops, the use of intersecting gill boxes and of "rub" aprons to insert a false twist, which is only temporary.

Machinery Layout A typical layout for a plant using the French system, running on an average of single 40s worsted yarn is given in Table 9.

TABLE 9 DETAILS OF A FRENCH-SYSTEM DRAWING PLANT

Operation	*Machines Required*	*Type of Machine*	*Deliveries per Head*	*Mechc*
1	one	Melanger int gill	three heads	—
2	one	1st int gill box	two heads; one delivery	—
3	one	2nd int. gill box	two heads; two deliveries	—
4	one	3rd int. gill box	two heads; two deliveries	double
5	one	Reducer	4 boxes, 8 bobb	double
6	one	Slubber	8 boxes, 16 bobb	double
7	one	1st intermediate	16 boxes, 32 bobb	double
8	one	2nd intermediate	21 boxes, 42 bobb	double
9	two	3rd intermediate	21 boxes, 42 bobb	double
10	three	Finisher	21 boxes, 42 bobb	double
11	twelve	Worsted mules	1⅞-in. diam	—
	fourteen	Ring frames	2-in rings, 3in dist	—

It should be observed that there are always nine to eleven operations in the French system of drawing as against six to eight in the Bradford system

Table 9 should give the layman a direct picture of the considerable amount of machinery required and the number of operations needed which are characteristic of the French system It will be noted that the machinery of the French system can be divided into three chief groups: gill boxes, drawing frames, and rovers or finishers The gill boxes are generally of the intersecting type.

Intersecting gill boxes When melanges or mixtures of different qualities of tops, vigoureux, or color mixtures are employed, the first machine is generally a melanger intersecting gill box It is called an intersecting or "intersector" gill box (and is used almost exclusively in Continental drawing) because its main features are two complete sets of screws and pinned fallers placed one above the other, each faller having a single row of pins The rows of pins in each set of

fallers "intersect" and are withdrawn alternately from the sliver It overcomes the objection to open drawing, that the wool sometimes rides over the faller pins The principle of the intersecting gill box is explained and made clearer by the side elevation of Fig 6

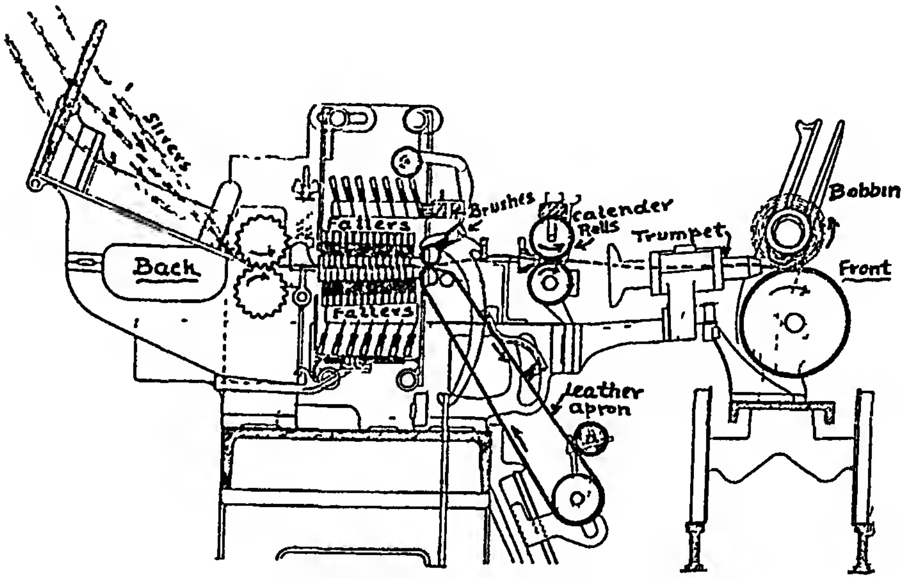

Fig 6 Principle and details of the intersecting gill box

Passage of the material It can be noted from the drawing that three slivers are fed to the intersecting gill box which originate from three upright cans or direct from top balls placed into an upright or vertical stationary creel When balls are used, sometimes driven creel stands are used, the ball is laid horizontal on two grooved wooden surface rolls, which are driven directly and rotate the ball so that it will deliver sliver at the rate required by the gill box The slivers pass through guides into a pair of back rolls (top and bottom), which are fluted and weighted by patented methods Assisting feed rolls are used on very short wools or blends of short and long wools so they will enter the needle field without plucking They are usually fitted between the back rollers and faller feed. From there the slivers, laid side by side, pass through two sets of pinned fallers, one set having its single row of pins pointing upward and the other row (coming from above) intersects the lower and has its pins pointing downward

(see Fig 6). Between them the sliver moves forward, as do the fallers with it, but the sliver is moving more rapidly. As the slivers pass forward, the fallers reach deeper into the wool fibers and leave the fallers as the gilled wool sliver enters the delivery rolls These rolls are fluted and the bottom one has an endless leather apron running around it but the top one is bare and fluted. A brush keeps lint and adhering fiber from interfering with the function of the rolls The leather apron cushions the nip of the case-hardened rolls and softens the pressure on the top roll, which is necessary to get a good grip on the wool fibers In the latest machines the flutes are diagonal, which is claimed to give an even and constant draft with an exceptionally smooth cushioning effect The fluting can be furnished deep, fine, or coarse according to requirements or individual preference. From the fluting, the single sliver (or amalgamated three slivers into one) passes on over a plate through well-polished and easily threaded funnels, these funnels are rotated by small skew gears and serve to insert a false twist into the sliver as well as to condense the size of the sliver The sliver now passes through a pair of smooth calender rolls and through a reciprocating guide trumpet onto a balling head, which serves to form a firm ball on a wooden core without any heads The arrangements vary according to whether there is one ball per head of machine or two balls (See the explanation of single meche and double meche below)

Production. The production of an intersecting gill box depends on the type of wool handled, the draft used, the pitch of the faller screws, and whether single or double meche is used. The faller speed is also a factor, hence it is not easy to give a relative production figure However, with a draft of six, 500 drops of fallers per minute, and 5/16-inch pitch screws, a single meche machine at 90 per cent efficiency will produce about 120 hanks (560 yards in one hank) per forty-eight hour week A machine with 3/8-inch pitch screws, 500 drops of fallers per minute, and a draft of six will produce only 144 hanks per forty-eight hour week at 90 per cent efficiency

The horsepower required is dependent on the size of the machine and the method of driving Driven from line shafts in a group about 3/4 h p per head is necessary or 3 h p for a four-head machine If driven by an individual motor, about 3 h p for a two- or three-head machine is required

Types of deliveries. The deliveries of intersecting gill boxes on the French system are of two types· can or ball. The balling head type

of machine is more common and can be made to give any of the following type of deliveries·

One single-meche ball per head
Two single-meche balls per head
One double-meche ball per head
Two double-meche balls per head

Here it becomes necessary to explain the word *meche* to the uninitiated Bobbins in the delivery head of intersecting gill boxes and all succeeding drawing machines which have one end or sliver per bobbin are known as "single meche" Those bobbins which carry two ends or slubbings per bobbin delivery are called "double meche" In other words, in succeeding processes it may happen that single-meche or single-end bobbins are put into the creel and come out double-meche bobbins in the delivery, i e, with two ends on a bobbin In another machine, double-meche bobbins are put in the creel and come off on double-meche bobbins in the delivery, that is, the bobbins have two ends or slubbing at both the feed and delivery

Stop motion The individual heads of a melange intersecting gill box, which may vary from one to six, can be stopped individually In order to eliminate waste, a device to stop the whole machine as soon as one head ceases to function has been invented

French-system or porcupine drawing machines The French drawing machines consist of a series of drawing, reducing, slubbing, and roving machines, which, contrary to the Bradford system, employ porcupine rollers after the first, second, or intermediate gilling is done on intersecting gill boxes Since no twist is employed in the slubbing and roving at any time, it becomes necessary to add a rubbing action to the roving in order to hold it together and package it on headless bobbins that will permit manipulation from machine to machine without breaking or severing the slubbing These will be explained in detail

While the machines are similar to each other, they vary only in fineness of construction according to the position they occupy in the set of French drawing An arrangement of such a set is shown in Fig 5 of a French drawing room Note the fine sawtooth roof, giving excellent and uniform lighting, high ceiling, and good lighting conditions Cleanliness and good working conditions prevail in such departments Note also that humidification is provided by overhead humidifiers Such rooms have to be provided and conditions of 80-90 per cent relative humidity must be maintained at all times The picture shows a typical American installation of French drawing

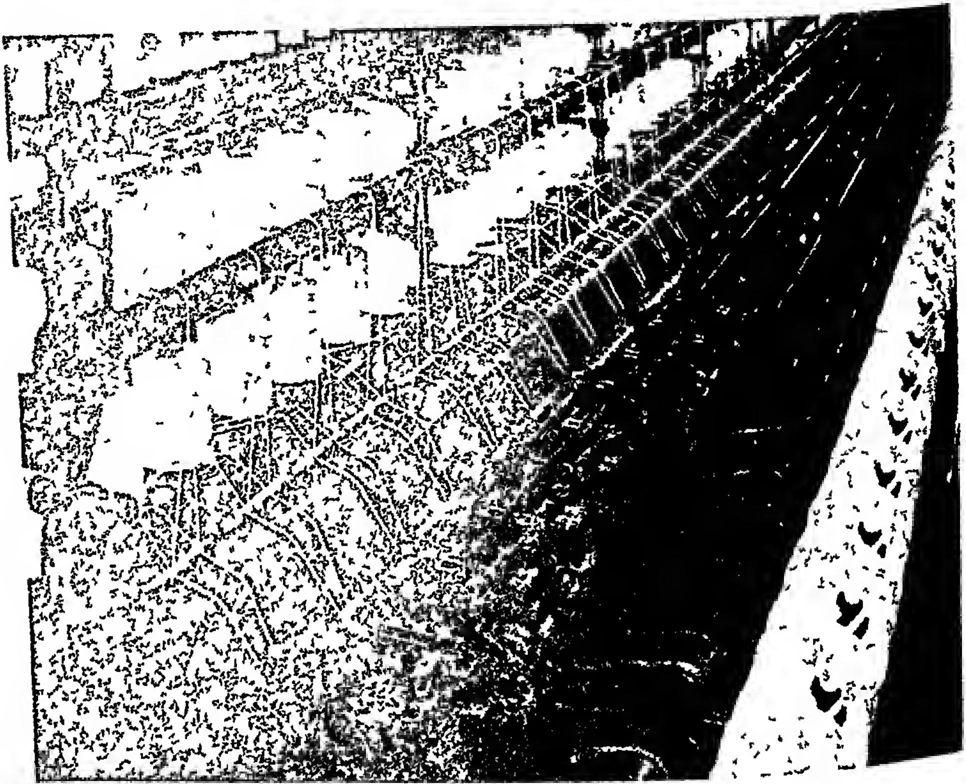

Fig 7 Porcupine drawing frame with one double-meche bobbin per head
Courtesy Forstman Woolen Co

Number of machines The sequence and the number of these drawing operations were pointed out in Table 9 They are variously known by names such as reducing, slubbing, intermediate (first and second and/or third) drawing, roving, finishing, etc. They are carried out on six to eleven machines in direct sequence to each other, which are charged with the doubling, drawing, and reducing of the top to the size of the roving ready for use on the spinning machine

Passage of the material The passage of the wool is practically the same for all French drawing processes The vertical creel at the back of the drawing machines provides room and a convenient place for the bobbins and also a means of guiding the twistless ends or slubbings The bobbins are supported by wooden skewers which fit into the center of the wooden-core bobbin tube They run with great ease when supported at each end Steps and cups carry the skewers and permit the bobbin to run very smoothly and lightly The slubbings are guided over glass rods and down to the traverse guides as shown

in Fig 8, a side elevation of a typical French porcupine drawing frame Traverse guides which move the slubbings to and fro as they enter the back rolls distribute the wear of the drawing rolls and rub leathers over a larger area than would be possible if no traverse was used

There are four distinct operations performed by a French drawing frame

1 Doubling or number of ends up or *meche*
2 Drafting or reduction of thickness of slubbing
3 Rubbing or condensation of delicate slubbing
4 Winding-on or packaging of slubbing

To perform these four functions or operations, certain mechanical devices are provided creel, guides, back rolls, carriers, porcupine rolls, front rolls, rubbing leathers, and winding or balling head The relative position of these parts are indicated in Fig 8

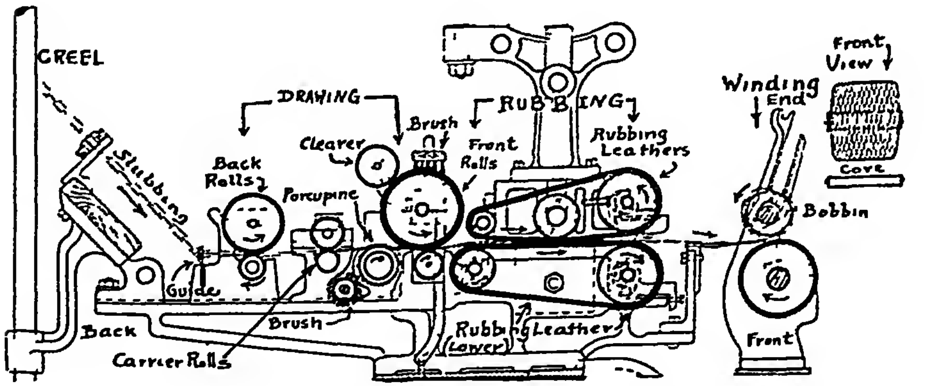

Fig 8 Details of a porcupine drawing frame

Doubling is done in the creel, guides, and back rolls Two sets of ends from two bobbins are run together and are made into one slubbing by one set of drawing rolls Drawing or drafting takes place between the back rolls and the front rolls Rubbing or condensing of the slubbing is performed by the rub leathers (similar to those in the finisher card of woolen yarn manufacture, see Chapter 10), whereas winding or balling is performed at the front of the machine, furnishing a ball, bobbin, or package of different size and yardage on each drawing frame

Function of the porcupine The French drawing frame employs a porcupine roller instead of pinned fallers in the drafting area between the back and front rolls. It consists of a brass roller studded with steel pins, which points backward about 60° with respect to its rotation The porcupine roll gives rectilinear or curvilinear drafting, the latter being a decided advantage on very short wools The purpose of the porcupine roll is to control the short fibers, while the long fibers are drawn through it by the front roll and its circumferential speed is slightly slower than the back rolls, 93% to 97% of the back roll speed It is fitted in a position as rear as possible to the front rolls, and a little higher than the nip of the rolls They exist not to function as draft agents, but rather as a means of floating fiber control The rollers directly preceding the porcupine roll are termed "carrier rolls"

Fig 9 Close-up view of porcupine roll in drawing

TABLE 10 DETAILS OF PORCUPINE ROLLS

Item	Medium Wools	Fine Wools
First Drawing		
a. Width of roller pin (in)	9½	8
b Diameter (in)	2.75	2.36
c. Rows of pins	48	36
d Pins in rows	107	151
e. Wire number	19	19
Last Drawing·		
a Width of roller pin (in.)	3.35	2.75
b Diameter (in.)	2	2
c. Rows of pins	66	60
d Pins in rows	159	169
e. Wire number	27	28

The top front roll is provided with a clearer roll covered with plush, and a brush to prevent laps and keep the top roll free from fiber lint Top rollers are covered with leather, roller felt, hard leather, or cork, over which parchment covers are sometimes used A weight and lever arrangement (not shown in Fig 9) provides the necessary pressure to the nip of front and back rolls

Function of the rubbing leathers and motion After the wool has been drawn through the porcupine by the front rolls, it is passed on directly to the rubbing aprons or leathers, which serve to rub the little slivers (twistless) into round, condensed, and firm slubbings They consist of two leather aprons, placed horizontally on two smooth revolving rolls, each rotating in the same direction as the wool and oscillating laterally as well They are set approximately ⅛ inch apart front and back and the roving passes between the two leather aprons The aprons are touching in the middle only through the weight of a wooden idler roll Porcelain guides hold double-meche slubbings the proper distance apart This action gives strength to the slubbing so that it can be condensed into a firm, round strand, which enables it to be manipulated in the creel of the next frame

The leather aprons are made of chrome-tanned unpolished leather with glued smooth joints, or of oak-tanned rubbing leather The lateral oscillations are created by means of double eccentrics and connecting rods with a rocker bracket The aprons can be adjusted to give three different lengths of rub traverse

Winding-on or packaging The firmly condensed slivers are now guided to the barrels of the balling device or "winding end," as it is named in Fig 8, which has a traverse corresponding to the width of the bobbin, the ends passing through the trumpet guide or, more recently, through an improved steel sliver guide onto the bobbin This is shown in a top view of a drawing frame, where the traverse guide is clearly noted The object of the balling head is to wind the delicate wool slubbing on a bobbin core or wooden barrel, varying in width from 15¾ inches on the first drawing, to only 8 inches in the rover The ball or bobbin is built up without wooden heads and, by means of a traverse, builds a perfect bobbin The traverse is obtained by means of a rack and pinion wheel and a buffer motion to absorb the shock when the carriage changes its direction The type of bobbin-build is illustrated in the side elevation of the French drawing frame Through changing the weight of steel spindles, tightness of winding can be regulated Density of winding is controlled by the speed of the traverse A quick traverse makes wide spaces, hence soft barrels and frequent doffing

4. Anglo-Continental System*

The regular systems of English and French drawing have distinctive features, and the yarns produced have generally been utilized for entirely different purposes The Anglo-Continental system of drawing is, as the name implies, a combination of both of these systems

This system has an advantage over the English system in being able to work shorter wools and tops of more uneven length, because pin control of the fibers is substituted for twist control in the first six or seven operations, where the sliver is thick and drafting against twist is least effective For the final operations, however, when the thickness of the sliver has been sufficiently reduced, the English system of draft against twist control is introduced, thus producing a roving which is smooth, solid, and in every way suitable for spinning on the regular type of English spinning frame

In recent years spinners using the English system have met with ever-increasing competition from users of the French system, partly because fashion has been running on soft-handling fabrics, and partly because the shorter wools, which the French spinners could utilize, have been cheaper than some of the longer wools necessary for the English system

The Anglo-Continental system of drawing is eminently suited for dealing with wools up to about 9 inches long, in qualities ranging between 50s and 70s, and containing a minimum average fiber length of about 2 inches An important feature of the system is its suitability for either oil- or dry-combed tops, and even blends of these can be worked successfully. Very short wools, however, should be worked on the French system of drawing, long luster wools, mohair, alpaca, goat hair, etc , are also unsuited for processing on Anglo-Continental machinery

As the roving operation of the Anglo-Continental system of drawing, together with the subsequent spinning operation, is on the English principle, the actual length of material which can be dealt with in a satisfactory manner on this system of drawing depends primarily on the sizes of rollers and fiber control capabilities through twist of the reducing, roving, and spinning machinery This will be readily understood in view of the fact that Anglo-Continental drawing is frequently introduced into mills to substitute for open drawing sets, to work in conjunction with existing roving and spinning equipment The Anglo-Continental drawing is of most interest to mills equipped

*Under American Patent No 1,795,351 by Prince-Smith & Stells, Ltd , England

with English combing, drawing, and spinning, because its introduction is easy and does not involve, like the French system of drawing, an entirely new combing, drawing, and spinning plant

Rovings may be produced which will give a yarn of almost any required characteristic, depending, of course, upon the blend of tops used Such yarns can have all the properties of those produced on the English system, or many characteristics of those on the French system, or even a combination of the features of both It is obvious, therefore, that the spinner who uses this new type of drawing is in a position to supply the particular type of yarn in current demand, the Anglo-Continental being more elastic and adaptable than either the English or French systems

The object of the invention is to provide means whereby oil-combed tops may be drafted with the aid of pin control The main features of the system are

1 A patent automatic stripping porcupine
2 High-speed revolving funnels
3 Control of the sliver during the drafting process

If an attempt were made to deal with oil-combed tops (3 per cent of oil) on machinery of the pure French type, it would be found that the porcupines become greasy and clogged up with waste, which in turn cause the wool to lap, and that the rubbing leathers in time get so saturated with oil as to become ineffective The features of the Anglo-Continental drawing just listed completely eliminate these two great objections and enable "wool in oil" to be drafted success-

TABLE 11 TYPICAL ANGLO-CONTINENTAL LAYOUT

Number and Type of Machines	*Doublings*	*Draft*	*Weight*
1 Intersecting gill box, 3 heads, 3 balls, s m	12	5 34	576
1 Intersecting gill box, 2 heads, 4 balls, s m	3	6	288
1 Intersecting gill box, 3 heads, 3 balls, d m	4	6	192
1 First Anglo-Continental drawing box 8 heads, 8 balls, d m , 17¾ in centers	2	4	96
1 Second Anglo-Continental drawing box, 15 heads, 15 balls, d m , 13¾ in. centers	2	4	48
2 Third Anglo-Continental drawing box, 10 heads, 20 balls, d m , 20½ in. centers	3	4	36
4 20-spindle Anglo-Continental cone finishers, bobbins 12 in x 6 in , 9¼ in pitch	3	4	27
4 40-spindle cone reducers, bobbins 10 in. x 5 in , two lines of spindles	3	6	13½
7 80-spindle cone rovers, bobbins 8 in x 4 in , two lines of spindles	2	6	4½

Total doublings for the set 31,104 Approximate production 7000 pounds per forty-eight hours of 4½ dram roving

fully with the help of pin control, which hitherto has been possible only with dry-combed wool.

There is a wide range of yarns which are being successfully produced on the Anglo-Continental drawing, and for such yarns it is found that the new method has many advantages over the English system

TABLE 12 ROVING WEIGHTS FOR VARIOUS WORSTED YARNS

(In drams per 40 yards)

Merino 70s

Qual Size	*Top Drs*
60s	1½
56s	1¾
52s	2
48s	2¼
44s	2½
40s	2¾
36s	3
32s	3¼
28s	3½
24s	4
20s	5
16s	6
12s	8
8s	9½

Crossbred 50s/56s

Equal Size	*Top Drs*
48s	2½
44s, 40s	3
36s, 32s	3½
28s, 24s	5
16s	8
12s	9
8s	15

Crossbred 40s/46s

Equal Size	*Top Drs*
40s, 36s	5
32s, 30s, 28s	6½
24s	8½
20s	10
16s	12
12s	16
8s	24

Crossbred Luster 32s/36s

Size	*Drs*
32s, 30s	6½
28s, 24s	9
20s	10
16s	12
12s	16
8s	24

English Luster 40s/44s

Equal Size	*Top Drs*
40s	5
36s	5½
32s, 30s	6½
28s	7
24s	8½
20s	10
16s	12
12s	16
8s	24

TABLE 13 NUMBER OF WORSTED DRAWING SETS IN UNITED STATES IN 1943

	Bradford	*French*	*Total*
Single	393	.	
Double	211	.	
Total	604	119	723

Source Bureau of the Census *Wool Manufacturing Equipment in U S. in 1943*

Chapter 14

WORSTED YARN SPINNING

WORSTED yarns are spun by four different methods, namely

1 Flyer Spinning
2 Cap Spinning
3 Ring Spinning
4 Mule Spinning

Rovings for worsted yarn spinning are prepared according to the French or Bradford systems of drawing

The changes in the use of these systems of spinning in the various branches of the worsted spinning industry is best illustrated by Table 1 which shows clearly a reduction in total spindles for the period in addition to a pronounced shift in both spinning systems to ring spinning with its greater productivity

TABLE 1. NUMBER OF WORSTED SPINDLES IN U S FOR 1936 AND 1943 CLASSIFIED ACCORDING TO SYSTEM

System	*1936*	*1943*
Bradford System total	1,533,000	1,286,271
Flyer	100,000	30,500
Cap	1,283,000	967,891
Ring	150,000	287,880
French System total	756,000	671,306
Mule	656,000	549,306
Ring	100,000	122,000

Demand for larger yarn packages plus increasing competition and the necessity for lower production costs has reduced cap spinning considerably, as its limitations have become more and more evident In this country flyer spinning is now used only for mohair, luster and carpet wools of 1/4s to 1/30s worsted count, the modern tendency is toward large package ring spinning in all worsted spinning The cap is still used extensively on fine crossbred and merino wools from 1/12s to 1/80s, whereas, the ring frame is becoming quite popular for the medium and fine merino qualities with counts of 1/12s to 1/70s, the mule is preferred by many for softness and fullness, and on the shorter merinos and crossbred wools, is used for dress goods and hosiery yarns

The worsted spinning field may be divided into two main sections, namely, *continuous frames* and *intermittent machines* Included in the former, are the so called "throstle" frames, such as flyer, cap and ring frames, whereas in the latter there is the worsted mule, which is distinctly different and should be considered separately.

According to the order of their introduction into the United States, the flyer frame was probably the first to be used, the cap frame next, followed by the ring frame (See Chapter 1).

TABLE 2
WOOL QUALITY VS SPINNABILITY AND MAXIMUM COUNTS[1]

Wool Qual No	*American Blood Grade*	*Aver Diam in Microns*	*Aver. Diam. in Inches*	*Max. Bradford or Worsted Spinning Counts*	*Worsted Spinning Counts Ordinarily Spun*
80	Fine	18 80	0 00074	80	52-70
70	Fine	20 30	0 00080	70	48-60
64	Fine	21 80	0 00086	60	40-50
60	Half Blood	24 80	0 00098	50	30-44
58	Half Blood	26 30	0 00104	46	28-40
56	Three-eights Blood	28 00	0 00110	38	20-36
50	Quater Blood	30 30	0 00119	34	18-32
48	Quarter Blood	32 50	0 00128	30	18-28
46	Low Quarter Blood	34 50	0 00136	28	18-26
44	Common	36 00	0 00142	26	16-24
40	Braid	38 00	0 00150	22	15-20
36	Braid	40 00	0 00157	18	6-16

[1] On the French system of spinning, the maximum worsted count, as represented by the wool quality number, can be reached with super wools

As mentioned under grading, the numerical terms designating the wool quality number have for their basis the maximum spinning capacity of the wool or the finest possible number to which it can be spun Table 2 shows the practical spinning limits of each wool quality in the Bradford system of spinning

Principle of worsted spinning The worsted spinning process is generally carried out in three separate steps as follows.

1 Final drawing-out or drafting.
2 Insertion of twist
3 Winding-on or packaging.

These are the types and sequences of operation which take place in spinning, irrespective of the particular system employed

The main objective in worsted spinning is the production from a

roving of a very uniform yarn of the desired thickness, requisite strength, surface, handle and appearance, put up in convenient forms such as bobbins, spools, cops or packages for later manipulation, inspection and use for knitting or weaving

The drafting is done by rollers in all cases, and is called *roller draft* as against the *spindle draft* used in woolen mule spinning The flyer, cap and ring frames differ only in the construction of their spindles, and their methods of imparting twist and winding the yarn on the bobbins

Of late, ring-spun yarns exhibit many characteristics of the mule and flyer-spun yarns, whereas cap-spun yarns are always more hairy and "wild" However, much depends on the length of the wool and its grade and character, as well as the care taken in preparation of the roving

FLYER SPINNING

Flyer spinning frames were patented by Richard Arkwright on July 3, 1769 It is said that the idea of the flyer originated with Leonardo da Vinci (1452-1519) and that the name "throstle" was given the frames in England because the noise made by the revolving metallic flyers sounded like a bird singing

The flyer system, the original method of continuous spinning, is losing ground rapidly because of its low output, but is practically indispensable in the production of heavy mohair, luster wools and carpet yarns

Considerable smoothness and luster are the main characteristics of flyer-spun worsted yarns The finest count that can be flyer-spun is a 1/32s worsted, because of the drag encountered

The flyer frame is built on the same principle as the open drawing machines It has back, front and carrier rolls to draw out the roving, and spindles with flyers screwed to the top to impart the twist and wind the yarn onto the double-headed wooden bobbins or paper tubes, the choice and dimensions of which are determined by the material in work, and the purpose for which the yarn is to be used. The machines are usually double-sided, equipped with spindles driven from the main drum at a low speed normally not more than 2,500 r p m Considerably higher speeds may be obtained with ball bearing spindles fitted to self-doffing flyer frames, a later development which permits spindle speeds of 3,000 r p m

The lifter motion of a flyer frame is of a different type than that of a drawing box Flyer frames wind the yarn onto bobbins by [illegible]

instead of the *bobbin lead* used in cap and ring frames. Friction drag is employed, which retards the barrel of the bobbin and permits the yarn to be laid on the bobbin in horizontal layers. Drag is obtained by washers of felt, leather, rubber or cloth Spindle lead on these flyer frames permits automatic or self-doffing, for which there are several methods Bobbins can be changed by means of rail changing, bobbin changing or reversible rails. The doffing motions are of particular importance when thick counts, which require frequent doffings, are being handled The doffing motions have been considerably simplified in recent years, and a frame can now be doffed in less than a minute

The production of fly frames is low, but that is unavoidable because the yarn would be too hairy and rough if spun at high-spindle speeds Such productions vary between wide limits, and no definite figures can be given Long drafts are used in preference to short ones Wools of eleven inch length, for instance, are given a draft of 12, and never less than the fiber length Spindles are of two types, those driven from the bottom, and those driven from the top with peg spindles Ratches and carrier settings require much attention Too much control causes curly yarns, while too little control produces irregular drafting and "twitty" yarns.

CAP SPINNING

The cap method of spinning is very popular in the United States, and practically all Bradford-spun worsted yarns are spun on this system The method was invented in America by Charles Danforth and is covered by a U S patent issued September 2, 1828

The differences between the cap and the flyer systems of spinning lie in the construction of the spindle, method of inserting the twist, and the winding-on of the spun yarn onto smaller bobbins A typical American machine is shown in Fig. 1.

Principle of cap spinning. The arrangement of drawing rolls is exactly the same as in the flyer frame or in a roving finisher The cap frame is adapted especially to fine counts of Bradford-spun yarns from merino and fine crossbred wools and can handle counts ranging from 1/12 to 1/80s worsted In these frames, the spindle is stationary, or *dead,* because it does not revolve, but the bobbins are rotated by means of a brass tube or shell with a whorl at the bottom which fits over the fixed spindle and rests on the lifter plate The lifter, guided by the stationary metal cap, moves the tubes up and down to wind the yarn on the small bobbins. There are three types of caps employed:

1. parallel caps (2 in diam, 6 in long)
2. taper caps (1⅞ in diam, 7¼ in long)
3. bell-shaped caps.

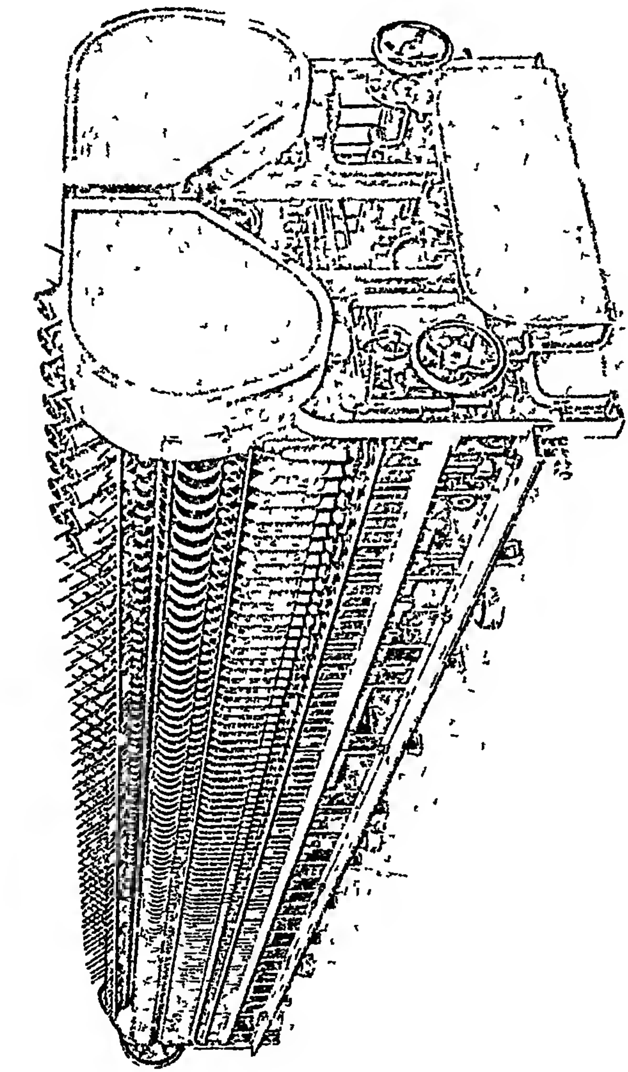

Fig 1 Four-foot cap spinning frame with patented adjustable roll stand, self-contained motor and chain drive—draft end
Courtesy Whitin Machine Works

The tapered cap (Fig. 2) is the most common type. Parallel caps are used for double-headed bobbins, and tapered and bell-shaped caps are employed for spools and tubes. Bell-shaped caps have a wide base to permit extra yardage on the spools.

The yarn package is positively driven and the retarding action of the balloon passing through the air, in conjunction with the "licking" around the edge of the cap, causes the yarn to be wound on the barrel of the package. The packages hold about two ounces of yarn. In determining the dimensions of the cap and the yarn package to be used, the distance between the bobbin barrel and the cap edge is taken into consideration This distance is decreased as the yarn counts become finer.

A much greater speed can be attained on cap frames, because the tube and bobbin drive usually operates at 6- to 7,000 rpm, though a speed of 9,000 rpm has been attained. This great difference in speed on cap frames allows greater production, but results in a much rougher and more hairy yarn, with a greater percentage of fly than the flyer frame It can be used on all sizes of yarn above 12s worsted count Because of its larger production capacity it is used extensively for pile and carpet yarns. Both warp and filling yarns can be spun on single-head bobbins or spools; for warp yarns the bobbins and caps are somewhat larger to permit more yarn to be wound on the spools.

Fig 2 Cap, bobbin and spindle assembly.

Cap spindles are easier to doff by hand than flyer spindles and self-doffing or mechanical doffing motions have not been adopted to the same extent as in flyer spinning frames. The doffing operation usually requires from one to two minutes during which time the operatives must remove the caps from the spindles, frequently damaging the caps. Deposit of oil on caps, snipped or dented caps and sticky caps cause trouble in spinning

Twist and twisting. The tube revolves around the stationary spindle and cap with the bobbin putting the twist into the yarn The tube rests on the lifter plate and revolves around the spindle carrying the spool or bobbin A groove cut into the bottom head of the bobbin fits into a pin placed at the top of the whorl

This prevents the bobbin from slipping The yarn comes through a pigtail guide centered over the spindle, and revolves around the smooth bottom rim of the metal cap, and is then wound onto the bobbin.

The cap and spindle are stationary, while the lifter rail raises and lowers the bobbin for the length of traverse desired on the bobbin, and according to the shape in which the yarn should be wound

The tube and bobbin revolve from left to right If the bobbin is wound too soft, there are two means of correcting it, namely, by increasing the spindle speed and by lowering the spindle rail Separators or metal shields prevent the balloons formed by the yarn from touching each other or becoming too large To give a yarn ten turns of twist per inch of length, the tube and bobbin are revolved ten times for every inch of roving delivered by the front rolls The amount of yarn wound on the bobbin is the same as that delivered by the front rolls, less a small amount of take-up due to this twist Because of the method of winding in the cap frame, the yarn is wound around the bobbin in the opposite direction to that in the flyer frame.

Amount of twist. The amount of twist put into any particular yarn varies considerably, and depends on the quality of the stock, the type of yarn, whether warp or filling, and the fabric to be made from it A yarn is only as strong as its weakest place, and long fibers generally require less twist than short ones The factors here are fiber diameter, softness, length and adherent properties of the wool Filling yarns usually receive less twist than warp yarns because they are not subjected to as much tension in weaving Cap spun yarns need more twist than those spun on a mule, ring or flyer frame. Suitable twists are determined by experience or users specifications.

For American machines, the twist gauge point for spinning frames is determined according to the following formula:

$$\text{Gauge point} = \frac{(\text{diam cyl})\quad(\text{double stud chain gear})\quad(\text{front roll gear})}{(\text{diam whorl})\quad(\text{cyl chain gear})\quad(\text{circum bot. frt. roll})}$$

Assuming a 10 inch cylinder is used, and a 1¼ inch whorl, front roll gear—268 teeth, circumference of bottom front roll—12½ inches, cylinder chain gear—34 teeth, and double stud chain gear—60 teeth, then a substitution of these figures would result in a twist gauge point of·

$$\frac{10 \times 60 \times 268}{1\,25 \times 34 \times 12\,5} = \frac{160800}{531\,25} = 302 \text{ the twist constant}$$

To find the turns of twist with a change gear of 60, divide this constant by 60:

$$\frac{302}{60} = 5 \text{ turns per inch}$$

To find the change gear for a certain twist, divide the twist into the constant

The above twists are theoretical and a loss of twist from 2 to 7 per cent usually occurs Hence, it becomes necessary to check regularly on the actual twist going into the yarn by testing the yarn itself on a twist tester (See Chapter 23).

Twist in single worsted yarns. As a general rule a spinner does not put any more twist into the single yarn during spinning than is absolutely necessary because twist is expensive, increases yarn costs and delays production However, twist in a worsted yarn serves several important purposes: *first,* it gives the yarn sufficient breaking strength to be handled satisfactorily in subsequent winding, warping, weaving or knitting operations, *second,* it adapts the yarn to the requirements of the final cloth or product made from it, i e, to be used for filling or warp, for men's or women's wear, knitting or crepe fabrics Such twist can be required by the purchaser or is specified by the spinner or by the mill's own weaving or knitting department

There are various degrees of twist used to accomplish different purposes The lowest twist is *soft* twist, which is generally used for knitting or embroidery yarns; *normal* twist, which is the twist given to weaving yarns, and may be subdivided into *warp* twist and *filling* twist. Warp twist is the twist which determines the maximum breaking strength of the worsted yarn and is of great importance where maximum cloth strength is required Filling twist, put into yarns used for filling or weft purposes, is usually softer than the warp twist, but higher than a knitting twist because of the tension existing during rewinding onto filling bobbins (if rewound) and in the shuttle during weaving.

The next degree of yarn twist is *medium hard,* which is used in hard or clear finished worsteds, for instance where the warp shows on the face and makes the face of the cloth It eliminates an excessive amount of shearing to clear the face of fuzz, which would be necessary if a lower twist were used. Yarns intended for warps in serges, gabardines, whipcord and tricotines receive this twist

The highest amount or *hardest* twist is put into worsted yarns to be used in crepes or crepelike fabrics, as well to obtain puckering or crinkling by shrinkage and corded or other effects. The breaking strength of this yarn, of course, will have been reduced through this over-twist

While each spinning mill has, to a certain degree, standardized these twists in their own spinning department, there is not as yet any general agreement among different mills as to what these twists should be Each mill has its own peculiarities as to qualities of stock run, the length and length variations of their wools and the system of spinning

used, i e , ring, mule or cap The type of fabric being woven, i e , suitings, coatings, etc , determines to a large extent the twist to be used in the yarns

Table 3 gives the single yarn twist for worsted yarns in turns per inch for regular combing wools with a length of 1½ to 3 inches, generally spun on the French system This table has been prepared for this book to serve as a guide and should not be construed as a standard or as an absolute minimum or maximum of twist to be put into sale yarn, for instance It does take in the whole range of American practice in worsted yarns The Bradford spun yarns have a slightly lower twist because of the longer wool used The terms *soft, normal, medium hard* and *hard twist* are relative and refer to the character of the yarns as influenced by the twist

Twist factor The twist constant or twist multiplier expresses a definite relationship between the yarn number and the twist As the yarn becomes finer, the twist increases in direct proportion to the square root of the yarn number For instance, in a 10s worsted yarn, the knitting twist is about 5 turns per inch, whereas, in a 50s worsted yarn it is about 12 turns per inch Therefore, the square root of the yarn number must be multiplied by a twist factor which will differ for each type of twist

TABLE 3 SINGLE YARN TWIST OF WORSTED YARNS

(Twists in turns per inch)

Yarn Number Worsted	*Soft Knitting*	*Degrees of Twist — Normal — Filling*	*Normal — Warp*	*Medium Hard*	*Hard Crepe*
10	5 30	7 22	9 72	13 36	16 82
15	6 47	8 82	11 92	16 35	20 59
20	7 49	10 19	13 76	16 35	23 77
25	8 36	11 41	15 37	21 10	26 62
30	9 15	12 50	16 89	23 12	29 13
35	9 89	13 50	18 24	25 01	31 43
40	10 58	14 42	19 45	26 70	33 62
45	11 23	15 28	20 63	28.31	35 63
50	11 83	16 10	21 76	29 87	37 59
55	12 43	16 90	22 84	31 34	39 43
60	12 98	17 68	23 85	32 73	41 20
65	13 48	18 38	24 80	34 06	42 88
70	13 98	19 07	25 75	35 33	44 47
75	14 48	19 75	26 60	36 58	46 04
80	14 96	20 40	27 53	37 78	47 58
85	15 42	21 03	28 36	38 95	49 03
90	15 87	21 63	29 18	40 06	50 43

On the basis of the twists given in Table 3, the factors or twist multipliers have been calculated and listed in Table 4 for the convenience of the spinner, analyst and technician These factors apply to French spun worsted yarns only For Bradford spun yarns, the factors must be modified slightly downward. This practice of using twist multipliers has been very valuable in the cotton yarn trade and when the woolen trade has become accustomed to the method, it may well become accepted practice in the woolen and worsted field as well. The table will be a guide to superintendents, spinning room foremen and control technicians who are interested in the correct twist for worsted yarns for their several purposes and want to adjust it to meet their own particular requirements

TABLE 4 TWIST FACTORS FOR WORSTED YARNS
(French Spun)

Degrees of Twist	*Worsted System Factor*
Soft	1 67
Normal, filling	2 28
Normal, warp	3 07
Medium hard	4 22
Hard or crepe	5 32

Equation Turns per inch = Factor $\sqrt{\text{Worsted yarn no}}$

Another formula which can be used by the designer to establish the twist for a new yarn, higher or lower in yarn number but with the same type or class of twist, is as follows

$$\text{Twist of new count} = \sqrt{\frac{\text{New number} \times \text{twist}^2 \text{ of known number}}{\text{known number}}}$$

Example: A 25s worsted yarn with 15 turns per inch is to be changed to a 30s worsted. What is the corresponding twist?

$$\frac{\sqrt{30 \times (15^2)}}{25} = \sqrt{270} = 17 \text{ turns per inch}$$

Direction of twist Single yarns such as are produced on flyer, cap, ring frames and mules, are spun with right hand or left hand twist. Left hand twist is often termed ordinary, regular or openband twist whereas, right hand twist is known as reverse, opposite or crossband twist Because of much confusion and many misunderstandings in the yarn trade, the A S T M has adopted a very simple means of designating the two types of twists employed in spinning worsted yarns specifically, and textile yarns in general. The definition is as follows. *A yarn*

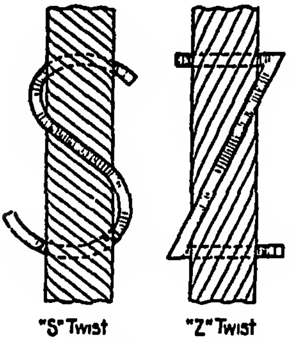

Fig 3 Types of twist in yarns

or cord has an 'S' twist, if, when held in a vertical position, the spirals conform in slope to the central portion of the letter 'S,' and 'Z' twist, if the spirals conform in slope to the central portion of the letter 'Z,' as shown in Fig 3

In American worsted practice, regular, left hand, or open-band twist corresponds to 'S' twist, and reverse, right hand or cross-band twist corresponds to 'Z' twist.

Other machine details Creels are made in single-peg creels, shell creels and box creels Single-peg creels have iron pegs, and support the roving bobbin with a small cup to reduce the drag. Shell creels provide shells to assist the bobbin in its revolution Box creels support the bobbin on both ends and are held in position by means of skewers

A horizontal traverse is given the roving by means of sliver guides, so that the rolls wear over a larger area than they would if allowed to run only in one position Usually, a traverse of 3/16 inches is used This traverse is reduced when thick roving is run

Generally, two rows of carriers are employed for short wools, and three rows for long wools. Their relative position depends on the amount of short wool in the stock and, ordinarily, one set is kept close to the front rollers The others are spread over the ratch distance between the front and back draft rolls Their surface speeds are a matter of function, which are supplementary to the back rolls, and not adjuncts to the front rolls. At no time do the carrier rolls exceed a surface speed of 2 1 over the surface speed of the back rolls The second set has a ratio of 1 75 1, and the third set from the front has a ratio of 1 5 1.

The lower front rolls are similar to those of the drawing machines in the Bradford system and are made of chilled and hardened steel provided with scratch flutes Their diameters are 3½ and 4 inches on all frames The top pressure rolls are large in diameter and are covered with leather or cork

Spindles are driven in two ways · by band drive and by tape drive Four spindles, two on each side of the machine, are usually driven by one band The bands or tapes are tensioned by weighted tension pulleys The tapes are joined by sewing, buckle fasteners or clip fasteners

Drafts. The draft used in spinning is determined by the size of the roving and the count of worsted yarn to be spun. Best practice dictates a small amount of draft in spinning, although long drafts with good quality rovings processed on modern spinning frames can be worked satisfactorily. It is a generally accepted rule that the draft in spinning, irrespective of the machine used, should not exceed the average staple length of the roving used Draft calculations involve the use of constants and length equivalents For illustration, assume that 40 yards of roving will be used. Since there are 560 yards in one hank of worsted roving or yarn, and 40 yards is used as the length basis, a relationship or constant can be obtained by dividing 560 by 40, which equals 14, or forty yards must be 1/14 of a hank Since there are 256 drams in a pound, one can obtain the weight in drams of 40 yards by dividing 256 drams by 14, which equals 18 3, and is considered the gauge point or constant for draft and size calculations, when dram rovings are employed For example. If a 40's worsted yarn is to be spun out of a 3 6 dram roving (per 40 yards), what draft is necessary?

The following rule applies. *Multiply the yarn size or count (40) by the dram roving (3 6) and divide the product by 18.3, which is the constant for 40 yards of roving*

$$\text{Hence} \quad \frac{40 \times 3\,6}{18\,3} = 8 \text{ draft}$$

If the roving is weighed in grains instead of drams, as is often the case in American mills, a new constant must be found, as follows:

$$\frac{7000 \times 40}{560} = 500 \text{ (constant)}$$

7,000 represents the grains in one pound, 40 is the yard basis of the roving and 560 is the standard number of yards in one hank of worsted. Hence, to find the draft which will spin a 40's yarn from a 100 grain roving, proceed by multiplying the counts (40) by the grain roving, and divide by the constant (500) for grain roving:

$$\frac{40 \times 100}{500} = \frac{4{,}000}{500} = 8 \text{ draft}$$

The above calculations and methods can be used to find worsted counts, drafts or rovings by merely substituting the known quantities and solving the equation for the unknown quantity.

To change a dram roving to a grain roving multiply by 27 35, and to change a grain roving to a dram roving divide the former by 27 35 The constant is found by dividing 7,000 by 256

RING SPINNING

Ring spinning was invented by John Thorp and patented in the United States Patent Office on November 20, 1828 However, its introduction to the Bradford system did not come until 1930, over 100 years after its invention, although it had been in almost universal use by cotton spinners for many years It had been adopted at least 20 years earlier by the European manufacturers of spinning machinery for the French system

In recent years there has been a definite trend from cap spinning to ring spinning by Bradford system mills, and from mule spinning to ring spinning by French system mills However, until recently the movement has been very gradual and, according to Department of Commerce statistics, there were about 287,880 worsted ring spindles in this country in 1943 A very large number of ring spindles are now in the process of installation

Credit for the pioneer work on ring spinning for the worsted system in this country goes to the Whitin Machine Works of Whitinsville, Mass The acceptance of Whitin ring spinning machinery has been more rapid in Bradford system mills than it has in French system mills, although many of the latter are now equipped with foreign ring spinning frames It is now possible to spin a bobbin of 3 inch diameter with a traverse up to 11 inches, holding 12 ounces of yarn (Fig. 4).

Fig 4 Ring and cap spun packages compared.

Large package ring spinning of worsted yarns will eventually replace small package cap spinning Coupled with long draft spinning, it constitutes the only way for worsted spinners to lower their production costs. The average worsted cap frame bobbin holds only 1 to 1¼ ounces of yarn and the average net weight of 100 bobbins is but 7 pounds while, with a

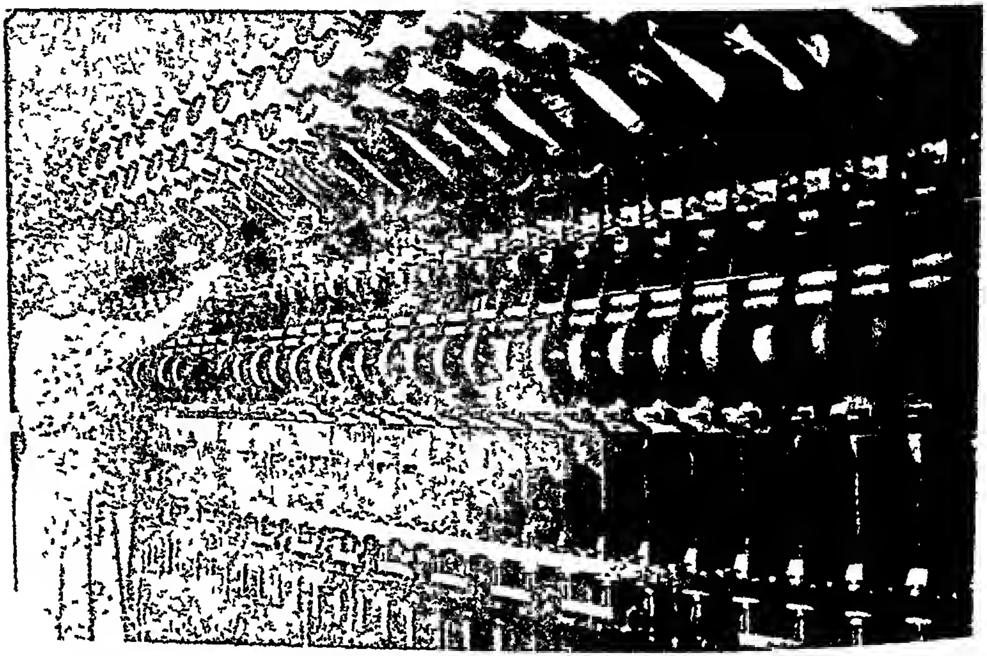

Fig 5 High speed, large package BW worsted ring spinning frame by Whitin (*Courtesy Arlington Mills*)

7½ inch traverse and 3 inch ring, the ring frame will produce almost 7 ounces on a bobbin or approximately 43 7 pounds of yarn per 100 spindles There can be no question that continuous worsted ring spinning holds the most promise for the American worsted spinner on both the French and Bradford systems

Ring spinning is most suitable for the production of worsted yarns varying from 1s-70s qualities The fact that large packages can be used here enables a spinner to produce long lengths of knotless yarns for weaving and knitting purposes Practical experience and scientific tests have definitely established the fact that the quality of the yarn does not suffer in any way from the use of large yarn packages They are preferred in many cases, because they contain only about 25 per cent of the knots found in cap-spun yarn

The creeling and the drafting arrangements on ring frames are very similar to those of the cap frame The latest Bradford system ring spinning frame is shown in Figures 5 and 6

Principle of the traveler and ring The method of inserting twist into the worsted yarn, after the roving has been reduced by roller draft to the

desired size, is the characteristic which distinguishes the ring frame from the cap, flyer and mule After the yarn leaves the front draw rolls, it is guided through a pigtail or porcelain eye centered over the spindle The yarn now passes down to the ring rail which carries a steel ring, turned perfectly true, and concentric to the spindle, fastened to the rail by a clamp The top rim of the ring is provided with a flange around which the traveler rotates There are three types of rings in common use:

1 Flange ring
2 Reversible flange ring
3 Vertical ring

Fig 6 Ring, traveler and large size bobbin assembly (Whitin).

The reversible flange ring has an advantage over the No 1 type ring in that its life span is twice as long The selection of the traveler depends on the following factors

(a) Yarn number
(b) Twist per inch in the yarn
(c) Inside diameter of the ring
(d) Diameter of the bobbin used
(e) Speed of the spindle

The traveler is set in motion by being dragged around the ring by the yarn As the yarn passes from the pigtail guide to the bobbin, it goes through the traveler opening, and then at right angles onto the bobbin Hence, the traveler acts as a twist inserter as well as a medium whereby the yarn is guided and wound onto the bobbin The size and weight of the traveler is governed by the factors mentioned above It is advisable to select travelers as heavy as the yarn will stand without excessive breakage This is necessary in order that the revolutions of the traveler will be sufficiently below the speed of the bobbin to maintain a tension on the yarn and permit the yarn to be wound onto the bobbin at the same rate as it is delivered to the spindle, plus the amount required by the contraction of the yarn due to the twist. (See Fig 6)

Lubricated rings The only factor which has prevented ring spindle speeds from being higher than those on cap frames is the [illegible]-

tion of the traveler against the ring This is being overcome rapidly by the use of lubricated rings as well as by improved travelers. While grease lubrication of rings has been found satisfactory and is preferred by some mills, the oil lubricated vertical ring which is supplied with a

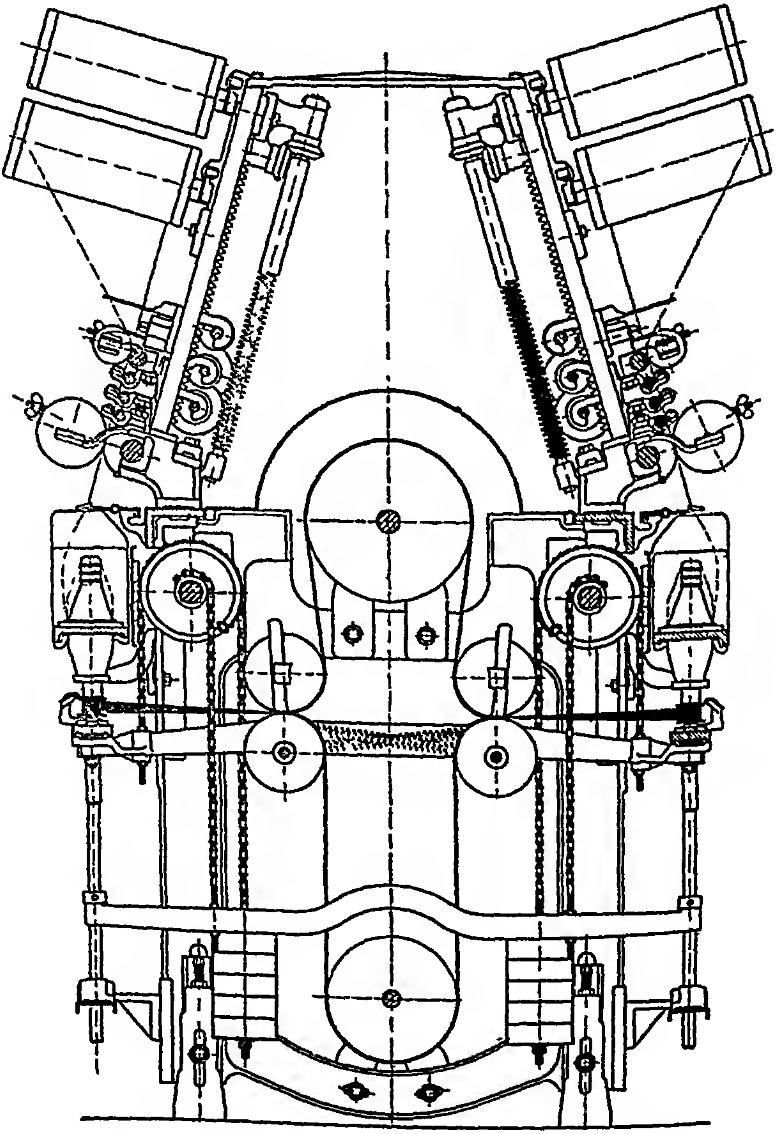

Fig 7 Cross-section of latest type Bradford ring spinner
Courtesy Whitin Machine Works

constant flow of oil from a reservoir located adjacent to the ring, is generally more satisfactory Not only does the automatic oiling feature require less attention on the part of the operator, but it also has the advantage that it delivers at the vital point only as much lubricant as is required This has brought about further acceleration in spindle speed, in some cases an increase of 1,000 to 1,500 rpm, bringing the total speeds up to 10,000 rpm The solution of the friction problem has put the ring frame into the preferred class of spinning machines In the newest vertical auto-lubricated rings the frictional drag of the traveler is reduced from 14 percent to 1½ percent as compared to the older type flange ring Improved ring travelers are available which are made from beryllium copper (2 percent Be—98 percent Cu) and have six times the life span of the regular high-carbon steel travelers The life span of the travelers may vary from a few hours to a month, depending on the spindle speed, the size and condition of the ring and the yarn to be spun or twisted For example, travelers used on two inch rings will last several times longer than the same travelers used on four inch rings under similar conditions Worn rings are especially detrimental to the life span of a traveler

Fig 8 French ring spinning frame showing front roll, yarn guide, ring rail with auto-lubricated rings, knee brakes and spindle drive details
Courtesy Forstmann Woolen Co

Balloon control The balloon which the yarn forms in passing from the front rollers and the thread board to the traveler, varies with the yarn tension On the old principle of the stationary spindle and traversing ring rail, the balloon changes in shape and size To obviate this and

prevent interference with the next spindle, shields are placed between the spindles Hoops are used in England to retard centrifugal action and help to control the balloon Another method is to guide the yarn directly from the nip of the draw rolls to the spindle top. In this case, yarn guides or pigtails are not used, causing the twist to go into the yarn through the top of the spind'e, and a small balloon to be formed just above the ring This method was not found practical

Another method of balloon and tension control is the Whitin patented reciprocating motion which provides for simultaneous travel of the ring and spindle rails, the two rails traveling progressively farther apart during the cycle of the doff The exact ratios of this simultaneous traversing motion make it possible to control balloon and tension very closely A shorter rail setting is permissible than is possible with any other motion, which allows a good spin with a longer traverse This motion has been found a definite asset in spinning the finer Bradford yarns The reciprocating motion is operated on square shafts with roller bearings The construction is simple and its motion is steady and even, each rail practically counterbalancing the other.

American Bradford System ring frames usually have 100 spindles on a side, 4-inch gauge; 3-inch diameter self lubricated rings ⅜-inch deep, 7-9 inch traverse, spindle speeds of 4000-7500 rpm with 90 per cent efficiency and producing 6-9 ounce packages on 1/28s to 1/32s worsted yarn (Fig 7.) Under such conditions, doffing costs for ring frames are reduced 50 per cent below those for cap frames Indirect spinning room labor is reduced 35 per cent. Ring frames make a smooth yarn that is practically knotless Doffing is necessary only once a day as compared to seven times a day on cap frames

The European French ring spinning frames (Fig 8) are normally built with 200 spindles on a side 3-inch gauge, 2-inch diameter rings and 8-inch traverse Spindle speeds up to 8000 rpm are possible on 1/32's with an average package weight of 3 ounces

HIGH DRAFT MECHANISM[1]

The draft basis of the French ring spinning frame with normal drafting equipment is 10 Some types of short wools will give the best results with a draft of 8 to 10, while 12 to 15 may be quite suitable for the longer wools such as crossbreds

The limitations of the ordinary roller drafting mechanism have stimu-

[1] *Ring Spinning and Twisting Frames (Continental System)* Prince-Smith and Stells Ltd Keighley, England pp 8 and 9

lated efforts to extend the scope of the high draft mechanism as there is no doubt that under certain circumstances, it would be an advantage to be able to work with higher drafts The fundamental feature of all drafting is fiber control and it is not surprising to find that the secret of increased drafts lies in the greater mechanical efficiency which ensures regularity in the flow of fibers The arrangement shown in Fig 9 fulfils these requirements satisfactorily

A small leather apron runs around the front and back carrier rollers (2nd and 4th line) the middle carrier roller (2nd line) acting as a support for the leather The steel top roller for the middle carrier (3rd line) is set slightly back and an additional top carrier is placed on the leather apron a small distance ahead of the middle carrier (3rd line),

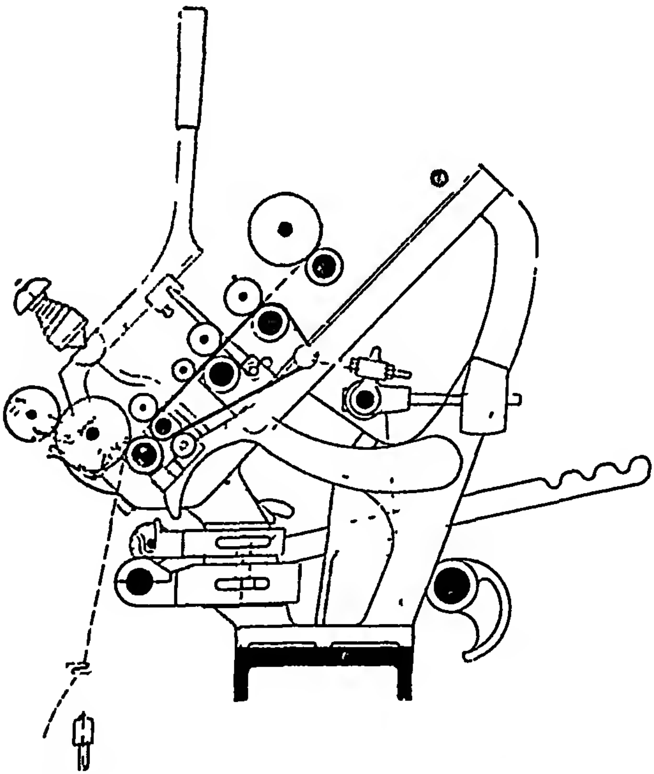

Fig 9 High draft arrangement diagram *Courtesy Prince Smith and Stells*

thereby deflecting the line of drafting The leather apron acts as a conveyor for the fibers and helps to obtain a more regular flow. A device is provided for applying tension to each section of the leather aprons also means of adjustment for each individual leather.

Experience has shown that if the wool is very irregular in length, a higher than normal draft cannot be applied with good results. even with the addition of a leather apron, though a better spin is likely to be obtained than with the standard drafting equipment. If however the wool is regular in length, 50 per cent more draft than usual can be applied by this arrangement with good results

It is quite obvious that high drafting in the spinning offers advantages such as these:

(a) One operation in the drawing may be saved.

(b) The production of a set of drawing may be increased, because a heavier weight of roving can be used to spin the same counts of yarn

(c) When rovings are kept for stock, high draft is an advantage, as a whole range of counts of yarn may be spun from the same weight of roving merely by altering the draft at the spinning operation

On the other hand, the addition of the high drafting equipment adds a complication to the machine requiring more attention and increased expense because of the necessity of renewing the leather aprons periodically. The presence of the leathers also increases cleaning difficulties

VARIABLE-SPEED SPINNING[2]

Varying yarn tension constitutes a real disadvantage in ring spinning. especially when running very fine counts on relatively large packages This is a mechanical characteristic of the ring spinning principle. At any given speed, the air friction of the balloon, and the traveler friction on the ring are approximately constant. To overcome them and pull the traveler around the ring, a tangential force of constant value, acting at the traveler, is necessary. This force is obtained from the tension between the bobbin and the traveler Because the angle of the yarn from the smallest to the largest bobbin diameter varies, a varying yarn tension is necessary to produce the constant tangential force required to keep the traveler moving (Fig 10.) This tension reaches its maximum value at the top of the winding motion when the bobbin is bare, and its minimum at the bottom when the bobbin is full and at its widest diameter. The fluctuation in yarn tension is transmitted through the yarn

[2]The material in this section is taken in great part from a paper by E. Honegger, *Papers AATT*, 2, 1, p 29.

up to the front rolls of the spinning frame so that the twist is inserted under varying tension with resulting differences in quality The effect of this quality variation is usually not noticeable until one approaches the upper limit to which a given material can be spun

Ring spinning with constant yarn tension can be attained by driving the spinning frame with a variable-speed motor correctly and automatically regulated. The speed must be constantly varied over the traverse cycle so that it will reach a minimum value at the top of the winding motion (see above), and then increased to its maximum at the bottom of the ring rail motion A variation of the order of thirty per cent (figured on the basis of the average minimum speed) is usually sufficient to equalize the yarn tension because the balloon and traveler drag vary as the square of the spindle speed Besides producing yarn of constant quality this procedure is claimed to give an increased output amounting to 10-15 per cent, because of the higher average spindle speeds which can be maintained Experience has shown that it is absolutely necessary for the spinner to have a thorough understanding of the theory and practice of variable-speed spinning to obtain the optimum result in quality and production

Variable-speed spinning is usually accomplished by the use of a 3-

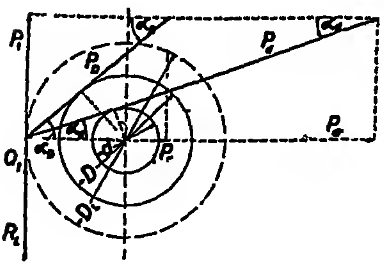

Fig 10

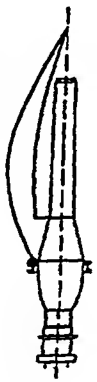

Fig 11

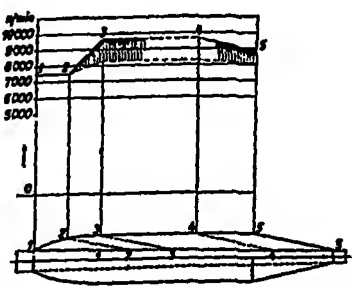

Fig 12

Fig 10 Diagram showing yarn tension between bobbin and traveler Qt-yarn air friction in balloon R_1-traveler friction on ring D_1-diameter of ring D-outside diameter of bobbin d-inside diameter of bobbin P-yarn tension Pt-tangential part of yarn tension

Fig 11 Balloon for top and bottom position of ring rail when spinning with constant speed

Fig 12 Diagram showing speed variation when working with spinning regulator.

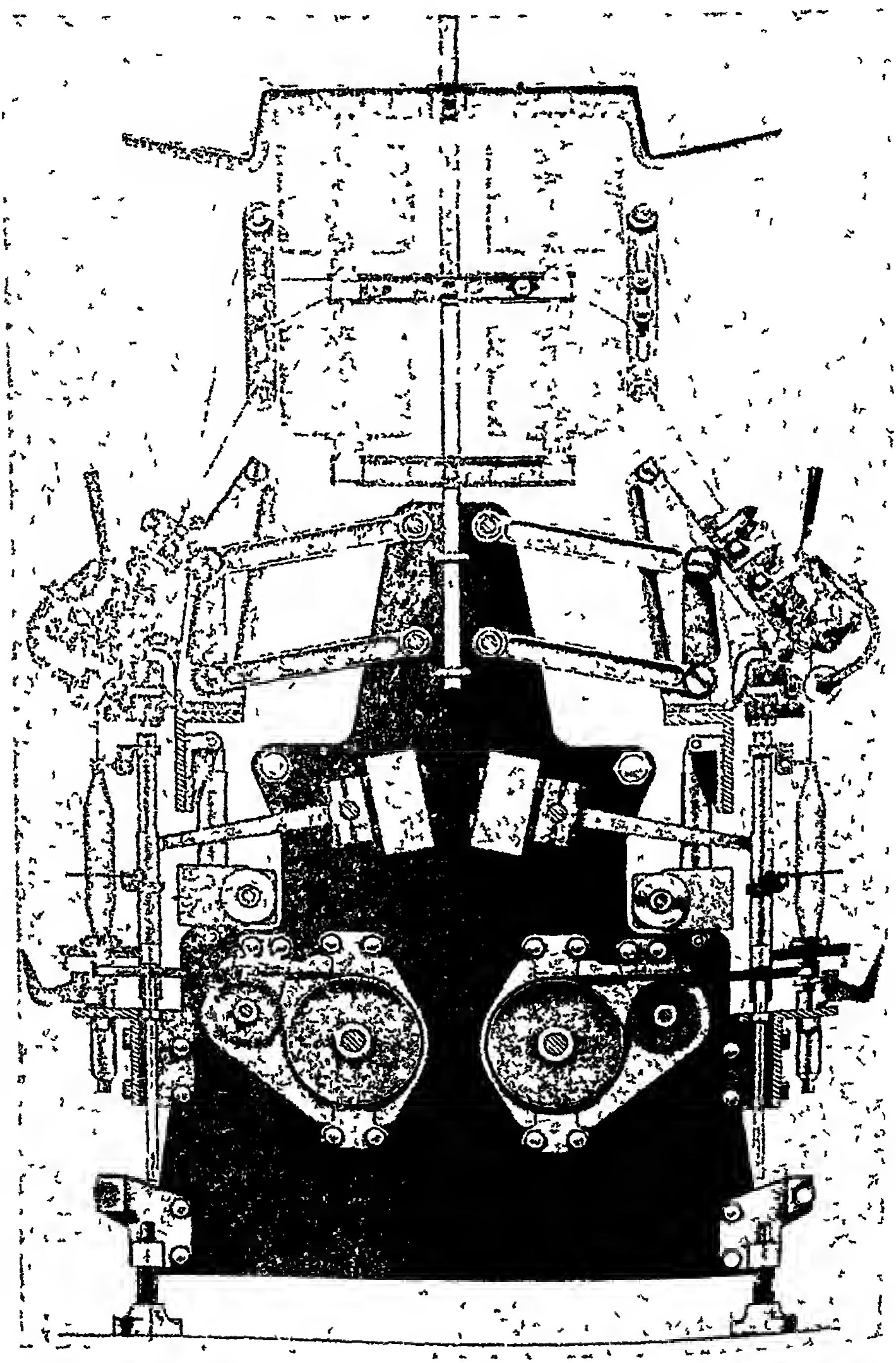

Fig 13 Cross section of McGlynn, Hays & Co high draft worsted ring spinner.

phase commutator motor whose brushes are shifted by the combined action of a basic cam which turns once per doff and a cyclic cam which makes one revolution per traverse of the ring rail The basic cam provides the variation of the optimum speed throughout the doff, while the cyclic cam provides the variation from maximum to minimum bobbin diameter as the ring rail goes up and down (Fig 12)

The latest development in the field of ring spinning is the machine developed by McGlynn, Hays & Co , Inc (Fig 13) The company is manufacturing a French-type worsted ring spinning frame, capable of producing a quality yarn from the coarsest to the finest counts, including those heretofore considered the exclusive domain of the mule The machine is built with the following features

High draft It has been mentioned before that standard French-type ring spinning frames have been generally limited to a maximum practical draft of ten Higher drafts have been made feasible by using a belt or apron system of fiber control Such equipment requires extensive maintenance and, if permitted to wear, will produce a poor, uneven yarn

These disadvantages are overcome in this new machine by the use of a patented six-line fiber-control drafting field Drafts of fifteen will produce a perfect yarn, which is in many ways superior to yarns spun with much lower drafts on conventional systems

The frame is built on a 3-inch pitch with 200 spindles on each side, using 11-inch traverse The diameter of the rings used is 2 inches, a dimension selected after exhaustive tests had established it as the most economical and practical size to produce the widest range of counts at top spindle speeds, with the highest yield per square foot of floor space occupied

To obtain a maximum output, with optimum spindle speed, the frames are generally equipped with variable or spin-regulator type motors Spindle speeds up to 12,000 rpm are possible

Optimum balloon length Of great importance, in the production of a yarn on large packages at high spindle speeds, is the necessity of maintaining an optimum balloon length The McGlynn Hays frame attains this by elevating the relatively slow-rotating fiber-control draft field to synchronization with the traverse This feature also permits the use of considerably higher spindle speeds, with complete freedom of vibration since the rapidly rotating spindles, driving cylinders and tension pulleys, are rigidly mounted

Individual drive for each side The use of an individual drive for each side of the frame permits the production of two completely different yarns on the same frame, simultaneously It also allows for

doffing, lot changing and adjusting, on either side of the machine, while the other side remains in complete uninterrupted operation

The spindles are of the break-ring type, tape-driven and equipped with S.K.F Model H M. 37 A bolsters Ring rails are made of extruded, re-enforced, angle-design aluminum alloy. A gear box, which is supplied for each side of the machine, includes a quick-change reversing lever for required direction of twist. Ball bearings are widely used throughout the machine

WORSTED MULE SPINNING

Mule spinning or intermittent worsted spinning prevails, as yet, primarily in the French-system worsted mills, but is not used at all in the English or Bradford system worsted mills in this country. (Table 1.) For worsted yarns, mule spinning is far too costly to allow a French spinner to compete with a Bradford spinner. However, the worsted mule makes an excellent soft yarn with a full handling quality not easily surpassed particularly for fine worsteds from Australian wools

In the worsted mule, drafting, twisting and winding-on are performed intermittently and not continuously as in the case of flyer, cap and ring frames, heretofore described and often referred to, especially in England, as "throstle" spinning frames

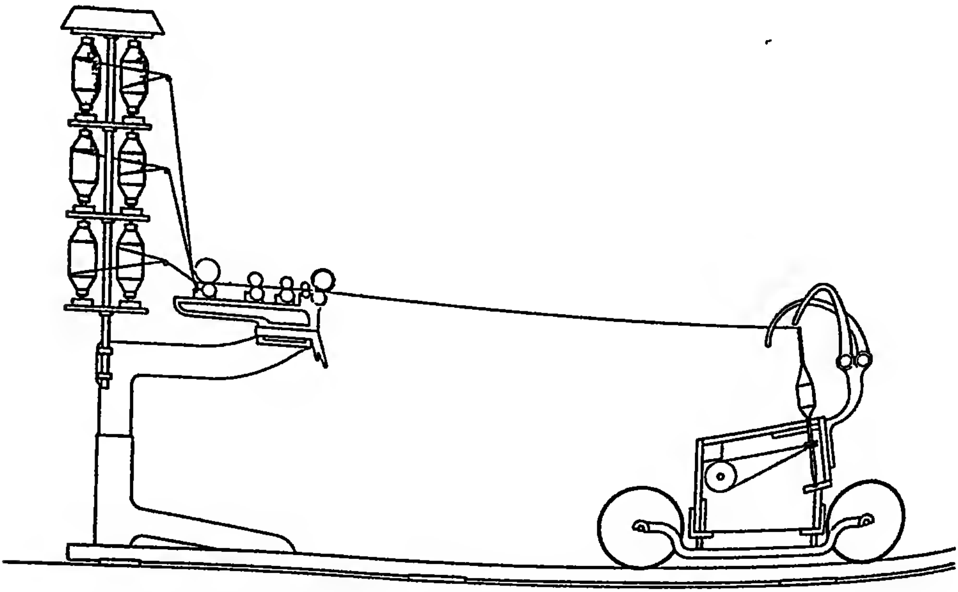

Fig. 14 Sectional view of worsted mule, showing its main parts

Drawing is accomplished by a set of five rolls—back and front set and three carriers—of small diameter, i.e., *roller drafted* and in that respect different from the woolen mule.

The distance between the various rollers or shafts should be approximately 80% of the length of the bulk of the fibers in the wool to be spun. An exception must be made with very short or very long fibers since the setting may become impossible because of construction limitations.

Example. The bulk of fibers of a certain top are 3 inches long. Eighty per cent of this equals 2.4 inches; therefore, the distance between the roller centers will be as follows:

1. Front roller and middle carrier (1st and 3rd line) 2.4 inches
2. Middle carrier and back carrier (3rd and 5th line) 2.4 inches
3. Back carrier and back roller (4th and 5th line) 2.4 inches

Twisting and winding-on are effected by spindles mounted in the rail of a carriage, which travels 60-64 inches from the rolls in one draw. Twist is run into the flat ribbon of roving as it leaves the drafting rolls. Inclined or tapered spindles are used to insert the twist, because they permit the roving to slip over the spindle tops. These spindles are driven by cylinders in the carriage which are driven by a rope from the rim or main shaft. The yarn is completely formed when the carriage reaches the end of its outward journey and has all the twist required. When that point is reached, the yarn at the top of the spindle has to be removed and, for that purpose, the spindles are reversed for a few turns, known as *backing-off*. At this time the faller wires come into play, taking up the slack in the yarn and governing the tension while the yarn is wound and built upon the spindle or the paper tube or wooden bobbin. The duration of the backing-off is largely determined by the size of the cop or yarn package.

The winding-on starts at the top of the bobbin and descends quickly, thus forming a tight binding layer. The winding faller then gradually ascends and then winds the yarn up the *chase* of the cop, as the carriage returns to its original starting position in front of the draw rolls.

The mechanics of the worsted mule are very similar to those of the woolen mule. (See p. 483.)

NEW AMERICAN SYSTEM OF WORSTED SPINNING

The so-called *American System* of worsted spinning which has recently been introduced by the Whitin Machine Works, is an outgrowth of that company's work on machinery for processing long staple rayon. As this new system cannot be used to process fibers shorter than 1½

inches, it is rather out of order to term it the Cotton System, although certain of its features were taken from the cotton system of spinning.

Both the roving and spinning frames were built originally to handle rayon fibers up to 3¼ inches mean length. Entirely new dressing frames had to be designed to process worsted tops successfully. The entire system was engineered for 56s to 64s quality worsted tops with a maximum staple length of 4 inches, and containing from 2 to 3 per cent of oil

It is estimated that there will be nearly 100,000 spindles of this system in operation by the end of 1947. This represents an annual capacity of about 18,000 000 pounds of 1/30s on an 80 hours per week basis. An additional 70,000 rayon spindles could be modified readily to further increase this large potential volume.

As presently being installed, the American system is as follows:

TABLE 5

RELATION OF SLIVER-WEIGHTS, DOUBLINGS AND DRAFTS

Operation	*Doublings*	*Drafts*	*Weight of Sliver* Used	*Weight of Sliver* Delivered
1 Breaker drawing	1	5	250 gr	50 gr
2 Inter drawing	5 or 6	5 or 6	50 gr.	50 gr
3 Finisher drawing	5 or 6	5 or 6	50 gr.	50 gr
4 Roving	1	8 to 24	50 gr.	2-6 Wstd ct
5 Spinning	2	Up to 14	2-6	Up to 1/40s
Total doublings	50 or 72			

Breaker Drawing A four metallic roll, four delivery head drawing frame has been designed to reduce the standard top ball to 50 grains per yard and coil it in a can, special precautions having been taken to eliminate all twist and minimize static electricity No doublings are undertaken in this operation

Intermediate Drawing A four metallic roll, four delivery head drawing frame is similar to the breaker drawing roll except for its creeling mechanism Five or six cans from the breaker drawing are put up behind each head and given a draft of five or six The resulting 50 grain sliver is again coiled in a can (Fig. 15)

Finisher Drawing This is an exact repetition of the previous operation

In connection with these drawing frames, it should be pointed out that there is no attempt to control the fibers during drafting with pins or twist, and that the total distances between the front and back rolls is fixed as 10½ inches. When fibers are used whose mean length is greater

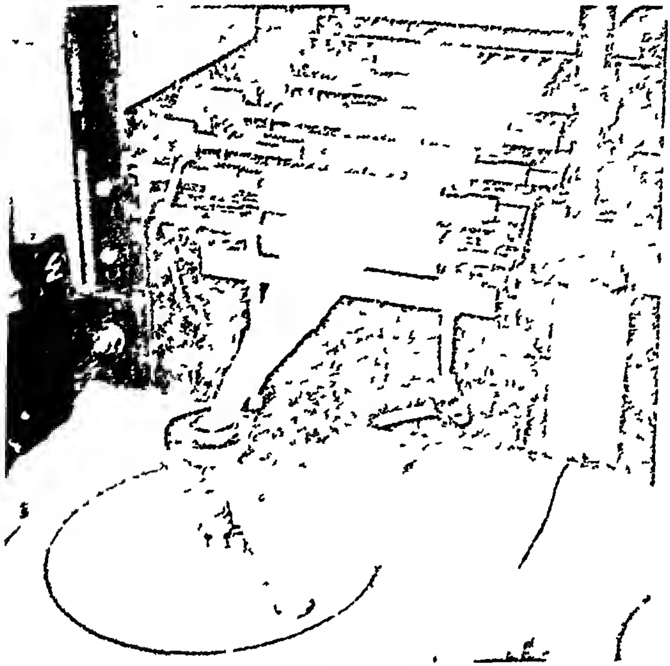

Fig 15 LW Intermediate drawing frame, roll details
Courtesy Whitin Machine Works

than 3¼ to 3½ inches, one of the intermediate rolls may be removed without adversely affecting the sliver evenness In general, the draft distribution, back to front, is 1 31 x 1 60 x 2 40, and the front roll speed is 100 feet per minute, although speeds as high as 170 feet per minute have been achieved with good results At 100 feet per minute and 85 per cent efficiency with 50 grain sliver, the production is 12 pounds per hour The cans are 12 inches in diameter and hold about 12 pounds of sliver when full

Roving The roving machine is a cotton type, cone driven flyer frame with two drafting fields separated by quarter turn plates so that the sliver enters the second field standing on edge The back drafting section consists of two lines of 1⅜ inch bottom steel rolls with cushion-covered top rolls The front section contains an improved double apron, long drafting system with a gear-driven top apron roll to avoid any possibility of slip This frame comes in any of the standard sizes, the most popular being 120 spindles 8 x 4 x 7 inches on which roving of from

2 to 6 worsted count can be made The spindle speed is from 750 to 900 rpm and the roving package contains about 15 oz. of material For example, a total draft of 18 (3.3 in the back section and 5 4 in front) is used to produce a 4.5 hank roving from one end of 50 grain sliver Production of this size roving at 85 per cent efficiency and 750 rpm spindle speed is about 0 3 pounds per spindle hour (Fig 16)

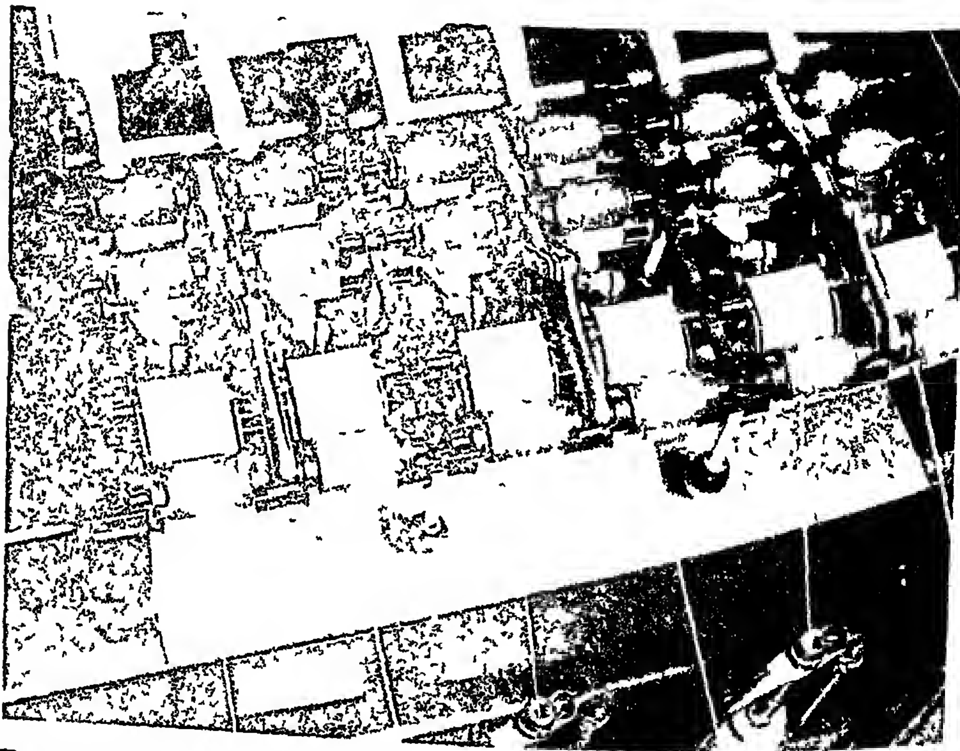

Fig 16 Whitin super draft system for roving *Courtesy Whitin Machine Works*

Spinning This is a 240-spindle ring frame of 4 inches gauge and 2½ inches oil lubricated rings, with an 8 inch traverse Up to the roller beam it is essentially a standard cotton spinning frame. From the roller beam up, however, it is a new design It is a double apron drafting type with gear driven apron rolls in the front section The total ratch is 7 inches, divided about equally between front roll and apron roll and apron roll to back roll. Two ends of roving are put up behind each spindle The maximum draft recommended is 14, with a break draft of 1 3 in the back section and the balance under apron control in the front section. Spindle speeds up to 7200 rpm may be run, depending

on the yarn count and twist Efficiency of 92 per cent is claimed on 1/36s worsted, with an average end breakage of 25 to 35 per 1000 spindles per hour (Fig 17)

Fig 17 Whitin long draft spinning system *Courtesy Whitin Machine Works*

Among the advantages claimed for the American System are (1) a considerable saving in labor cost, estimated as high as ten dollars per spindle per year on a two shift basis for a 4000 spindle mill, (2) the double apron drafting on both the roving and spinning frames provides superior fiber control

The disadvantages include (1) the necessity for highly uniform worsted tops because of the small number of doublings, (2) difficulty of blending colors because of the small number of doublings, (3) lack of flexibility, as only tops of certain rather narrowly defined lengths can be used

OTHER WORSTED SPINNING SYSTEMS

In addition to the American system there are a number of other systems under development for the spinning of all worsteds and blends thereof on a simplified basis, having for their purpose the reduction of operations necessary to produce yarn from standard tops.

The Saco-Lowell Shops, for example, have developed in the last years, new roving and spinning machinery suitable for incorporation in such a system Their long staple roving frame (Shaw U S. Patent #2, 323,882) is an example (Fig 18)

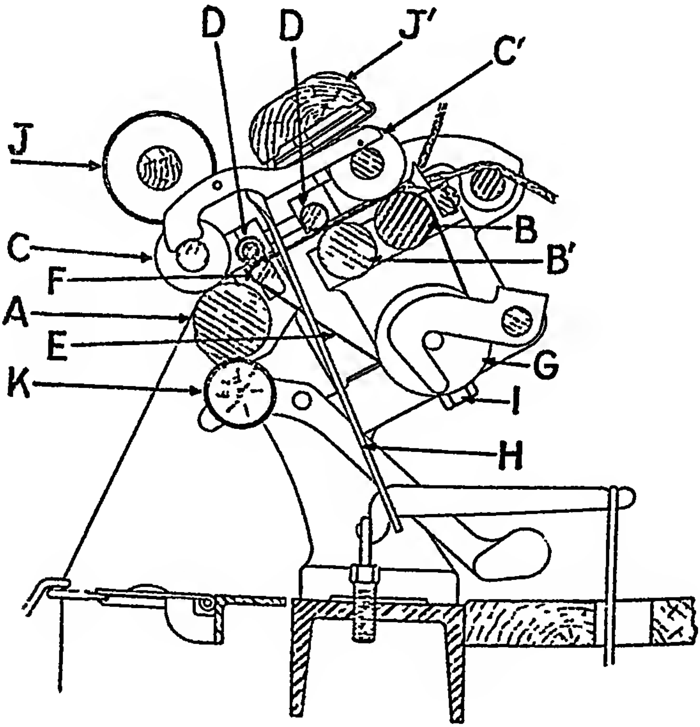

Fig 18 Adjustable Model Z Roving Frame with Rolls Open

A—Steel front roll, 1⅛" diameter
B and B′—Knurled middle and back rolls
C and C′—Cushion top rolls, 1 5/16" diameter
D—Control rolls
E—Apron
F—Nose bar
G—Tension pulley.
H—Z-Type Saddle and stirrup assembly
I—Adjustment for roll stand
J and J′—Combination top clearers
K—Bottom clearer.

The distinctive unit of this drafting unit is the roll assembly Three top rolls work in conjunction with four steel bottom rolls The first, third, and fourth line of steel rolls are the conventional design with special fluting to assure a positive grip for the draft of the strand as it diminishes in size during its passage through the assembly The second roll is a plain, unfluted roll

An inspection of the section shows that the drafting operation takes place in two consecutive but separate zones as follows

The *back* or *break-draft* zone extends from the nip of the back rollers to the nip of the large top roll with the third bottom roll Here the strand is given a substantial draft with a loosening of the fibers, which removes the hooks and hairpins As the strand leaves the back of breakdraft zone, it enters the *second* or *final drafting* zone, which extends from the nip of the third bottom roll and the second top roll to the nip of the front roll

In the *final drafting* zone, the orthodox middle rolls of the usual three-roll frame have been replaced by the assembly shown, consisting of the large top roll, the small second bottom roll, and the regular-size third bottom roll The large top roll is positively driven through frictional contact with the third bottom roll and, at the same time, spaced from the second bottom roll by means of collars on the ends of the top roll With this arrangement the roving is gripped firmly at the bite of the large upper roll and the third lower roll for drafting and, without the use of belts or aprons, a regulated slight pressure is supplied between the large upper roll and the second lower roll during the draft, contributing materially to the uniformity of the roving With this assembly a draft as high as eight may be effected successfully without impairment of quality on long-staple fibers of varying lengths and blends This draft, in combination with the back draft, can produce a front draft as high as 24

Spinning Frame The roving produced on the previously described roving frame can be processed on the Saco-Lowell model Z-2 spinning frame The chassis of this frame is exactly like a standard cotton ring-spinning frame but above the roller beam it is equipped with a high draft mechanism using leather aprons as described previously under *High Draft Mechanism*

Twisting or Folding

Since all types of spinning machines produce only single worsted yarns, it becomes necessary to fold or combine two or more yarns of the same or different count or character to make a stronger thread, or to obtain special or novelty effects They are known as doubled, ply or twisted yarns, and serve many special purposes

Machinery used. The machinery used in this department of a spinning mill depends largely on the extent to which this work is done and whether it is done for customers or for the mill's own weaving department Because of greater demands for fancy or novelty twists this particular branch of the woolen and worsted industries has grown considerably and is more commonly done by special plants, which are devoted entirely to that work The varying requirements of the different branches of the textile trade demand a wide range of machinery

Winding to Change Yarn Package

It often becomes necessary to change the spinning package to some other form to permit its use on a twister, etc To dye the yarn, a yarn reel is required to convert the spinning or twisting package into hanks or skeins for skein dyeing If it is to be dyed by the spindle system, it has to be wound onto perforated paper or metal tubes If the yarn is to be used for filling and is on jack spools, it becomes necessary to use a filling winder also known as a carriage winder or a Universal filling winder If the yarn is to be shipped on tubes or cones it becomes necessary to use cone winders, which can be changed over to wind parallel tubes as well If yarn is to be dyed on jackspools it becomes necessary to use a spooler

The forms in which worsted yarns are sold by the mills and on the market are quite numerous, and differ practically with every mill It would be impossible to mention them all or describe the sizes, shapes, weights and materials used for this purpose No uniformity or standard practice exists in this field

Novelty twisting For ordinary twisting mills employ cap, ring and flyer spinning frames, changed to suit each purpose Frames are employed primarily to insert more or crepe twist into single yarns, or combine or fold two or more yarns putting in twist the reverse of that of the singles In the woolen trade, twisting is done directly from spinning packages Ring frames have the advantage that they can be used for both purposes The operations are comparatively simple, except when it comes to special effect yarns such as the following types

1 loop yarns
2 nub yarns
3 core yarns
4. spiral yarns
5. slub yarns
6 flake yarns
7. chenille yarns
8 ratine yarns
9. sponge yarns
10 crinkle yarns
11 combination twists
12 mixture twists

The above all require special twisters or attachments to ordinary twisters They involve differences in tensions, introduction of nubs and flakes, formation of yarn loops, high and low twist sections and a great variety of devices too intricate and numerous to be included here However, they form the basis of an important business, which has become a necessary adjunct to the manufacture of novelty woolen and worsted fabrics

An example is shown of a device to produce nub yarns with an oscillating thread guide In Fig 19 the core thread 1 is delivered by a pair of rollers A directly to the spindle at a constant speed The novelty thread 2 is delivered from a pair of rollers B over to guide bar C, down

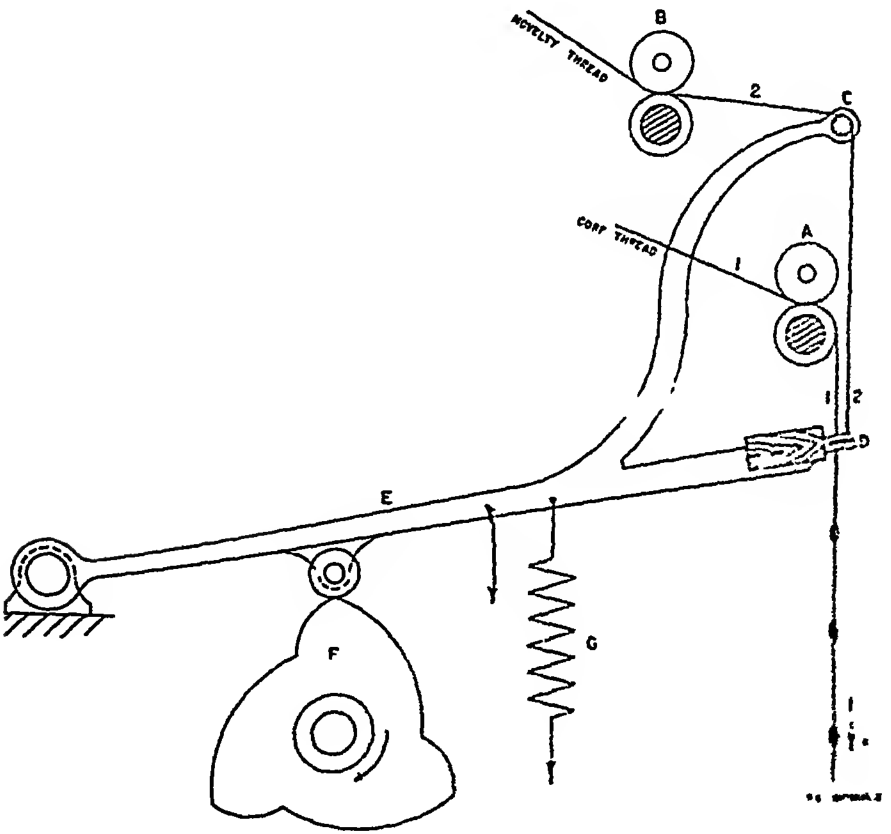

Fig. 19. Diagram of mechanism for producing nub yarns

through a thread guide D, joining core thread 1 at this point The thread guide D is part of the oscillating arm E, whose up and down movement is controlled by a rotating cam F The spring G keeps the arm E in constant contact with the cam

The downward speed of the stroke of arm E is close to the delivery speed of yarn 1, therefore yarn 2 is wrapped around yarn 1, forming a nub During the upward movement of arm E, thread 2 wraps itself around core yarn 1 in a steep spiral The size of the nub, as well as the spacing between the nubs, depends on the delivery speed of both yarns as well as the shape of the cam

Twist Setting and Yarn Conditioning

Newly-spun single woolen and worsted yarns, especially those containing extra, i e, more than ordinary twist, and plied yarns and novelty twists required for knitting and for warp or filling purposes, have a tendency to snarl, curl-up, untwist and kink when tension on the yarn is released In such cases, a twist setting operation is resorted to which has for its purpose the "deadening of the liveliness" of the newly-spun yarn to stop the curling, snarling and kinking of such yarns when they are unraveled or unwound from their packages Newly-spun yarns should not be used immediately but should be given a "rest period" They are subjected to a conditioning or accelerated setting process Various methods are in common use for this purpose.

In the oldest method the warp or filling bobbins which are loosely placed in trucks or baskets are simply wheeled into a steam chamber where they are subjected to low pressure steam for 20 to 30 minutes Some machines blow the steam directly into the chamber, others bubble it through water To have an even steamed effect throughout the bobbins, it is necessary that the humidified hot air be circulated In one of the newer types of box steamer, the humidified air circulates through the trucks of yarn under slight pressure with the aid of a vacuum Temperature, humidity and length of treatment are all controlled automatically, no manual attention being required except for loading and unloading A light or other signal indicates the completion of the cycle The machine is built to handle from 1 to 6 trucks, or up to 750 lbs of yarn

A new conditioning unit has been introduced and has proven very effective on woolen and worsted yarns (Fig 20) It is based on the water vapor principle The patented construction eliminates any possibility of surface wetting by particles of water falling from the

ceiling of the conditioner Yarn in this conditioner need not be covered Temperature, humidity, air velocity and time of operation are controlled and visible charts show how the operation is progressing When the operating specification for any type of yarn has been obtained it is only necessary to set the control hygrometer at the proper point and turn on the time clock for the desired period At the end of the specified time the clock will shut off the machine automatically

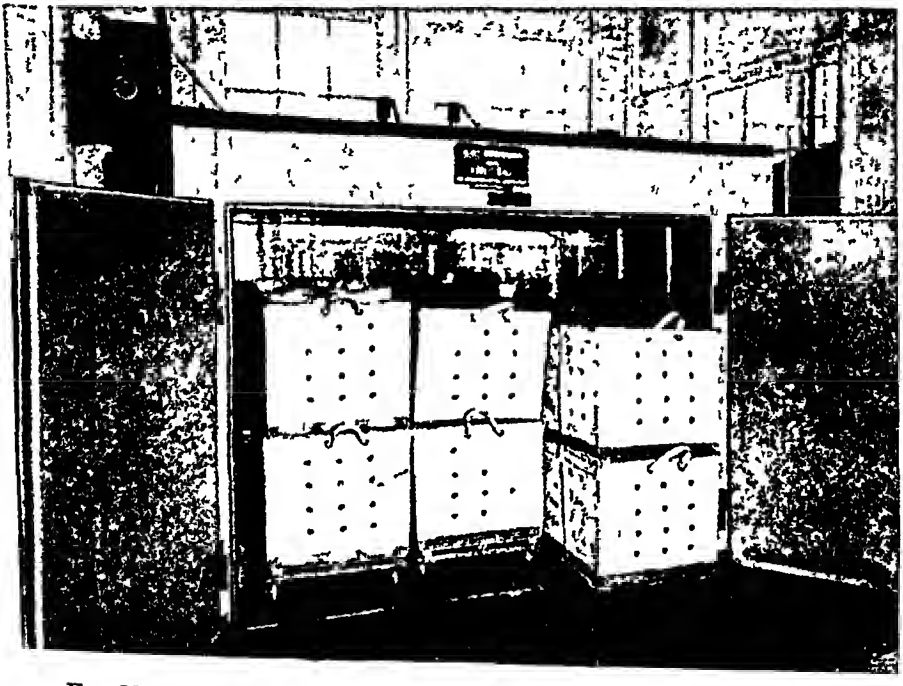

Fig 20 Yarn conditioner *Courtesy The Industrial Dryer Corporation*

Some mills use a traveling slat conveyor or apron, on which the yarn bobbins, cops, pirns, cones or skeins are placed The yarn packages are distributed evenly over the moving conveyors by a spreading attachment and pass through or under four sets of sprays Between each the packages are turned over, insuring moisture on all sides The amount of liquid applied to the yarn is accurately measured by an automatic control The yarn remains in the machine from 15 to 30 minutes

The conditioned yarn is then carried to the delivery end of the

machine, where it is placed on conveyors or floor trucks ready to go to the weave room or storage room Such an apparatus can handle 400 to 800 pounds of yarn per hour. It is known as the Hygrolit conditioning system

Yarn Storage If yarns have been spun for stock and are not to be used immediately, it is wise to store them in a special room in a cellar, where moisture conditions are easily maintained at 70-75 per cent relative humidity by means of humidifiers In any case, stored yarn will come to complete equilibrium in about a week to ten days The liveliness of the twist will be gone and it will no longer be necessary to condition the yarn following storage It is advisable to cover the boxes with waterproof paper to prevent water condensing on walls, ceilings, or pipes, from dropping on the yarn and causing subsequent stains, spots, and imperfections in the woven goods.

Chapter 15

PROCESSES PREPARATORY TO WEAVING

AFTER woolen and worsted yarns are spun for warp and weaving purposes, they are found in various kinds of put-up, on spinning bobbins, twister bobbins, paper tubes, cops, and wooden spools of all sizes, shapes, and weights, depending on the method of spinning employed and into which form the yarn has been put for shipment to the user. Since many weaving mills, especially in the worsted branch, do not spin their own yarns and those in the woolen branch get some of their yarns from widely different sources, within or not within their direct control, the picture is complicated However, in whatever form the yarn is received or bought, in most mills it requires a rewinding process The rewinding of yarns differs according to the particular equipment of each worsted or woolen mill

Worsted Yarn Rewinding

Some yarn rewinding is necessary when warp yarns are subjected to a worsted-yarn-dyeing process The two dyeing methods are skein or hank dyeing and jackspool dyeing Both are described in the chapter on dyeing

Before dyeing by the skein method the yarn must be wound into hanks or skeins with necessary leases to prevent tangling and snarling An outside dyer will return the yarn in hanks but, if the yarn is dyed in the mill, it must be skeined in preparation for dyeing and then rewound from skeins to either cones or cheeses (parallel tubes) For this reason a hank winder or yarn reel is found in most worsted-weaving plants For rewinding skeins into cones for warp, a Universal coning machine or tubing machine is generally employed on yarns for warp purposes This applies primarily to plied yarns, as fine single and highly twisted worsted yarns are rarely skein-dyed The size of the packages depends largely on what equipment is used in the warping department and what size the yarn creel can hold The tendency, of course, is toward large cones and cheeses to assure a yarn supply of standard numbers for a long period without replacement. On

sample warps, the yarn lot is divided so that a predetermined number of ends can be used on the warpers, if that method of warping is employed Some mills even rewind onto wooden-head spools of 5 to 6 inches diameter, but the tendency is toward cones and cheeses to get away from the tension factor in unrolling spools

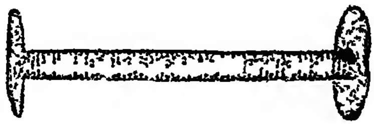

Fig 1 Empty metallic jackspool showing perforations

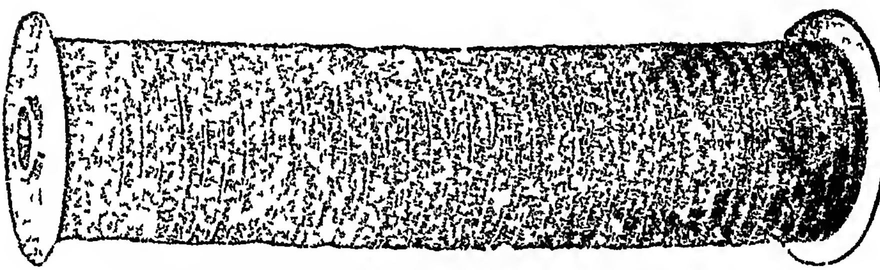

Fig 2 Full metallic jackspool with dyed yarn
(*Courtesy Franklin Process Co*)

On fine, single, and dyed worsted yarns for warp purposes, the jackspool method is preferred by many mills Here, the yarn can be wound into two different forms, both being extensively used according to how a mill is equipped The yarns are wound from cops, bobbins, spools, paper tubes, or cheeses onto a perforated and hollow core (Fig 1), double-headed metallic jackspool usually 32½ or 40 inches long with heads of 11 inches diameter and a core 6 inches in diameter Such spools (Fig 2) contain forty or forty-eight ends of worsted yarn and are wound in preparation for dyeing by this method They can be wound at the rate of 60 to 120 yards per minute, varying with different yarn sizes After dyeing and drying, these spools can be used directly in the making of warps by the section or reel method of woolen warping and to some extent in the warping of worsted warps by beam warping

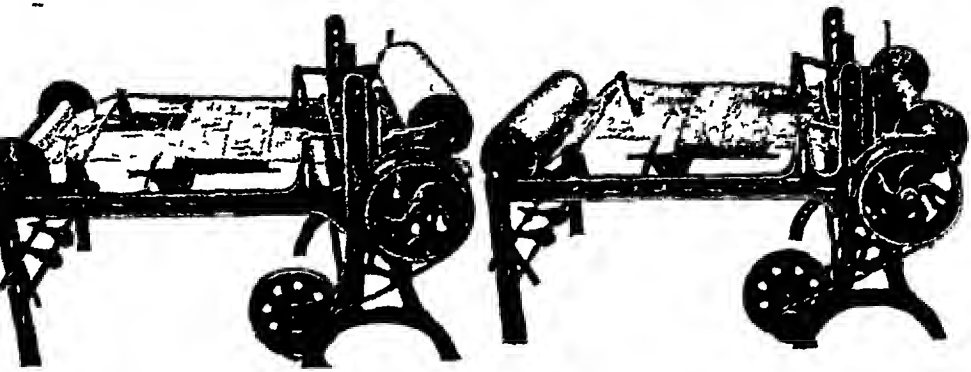

FIG 3 Winding on and off of metallic jackspools
(Courtesy Franklin Process Co)

A second, but less common, method is that of dyeing worsted warp yarns in small package form These packages are usually 3 or 6 inches in height and about 4¼ inches in diameter, depending on the yarn size Very fine yarns are put on 3-inch packages weighing about 8 ounces each For all other counts, the 6-inch package is used, holding about a pound of yarn The core of the package can be a metal spring covered with a knitted cotton jacket or perforated plastic tubing On this core a full complement of yarn is wound with a moderate tension, so as not to create too hard a package, which would make it difficult for the dye liquor in the vacuum-dyeing machine to penetrate the yarns These packages, after dyeing and drying, can be used directly in the warping creel in both beam warping and section warping, in the case of woolen yarns, by putting skewers into the cores and rotating them while unwinding or without rotating by unwinding them overhead, the latter being generally preferred This method eliminates an extra rewinding of the yarn, which should be avoided as far as possible on fine, dyed yarns Carpet yarns and other coarse woolen yarns are generally not dyed in this type of package, nor are lofty knitting or embroidery yarns

Single worsted yarn for many years was almost entirely spun on cap frames and the typical bobbin was either a double-headed bobbin, holding about 1½ to 2 ounces with a warp wind, or a single-headed bobbin, holding about the same amount with a filling wind In recent years, however, more worsted spinning has been done on rings and many of the old cap frames have been changed to ring. The bobbins are made considerably larger, anywhere from 4 to 7 ounces

Single yarn for the knitting trade was wound directly from the

spinning bobbins onto knitting cones Where yarn was used for filling, it was generally wound directly from the spinning bobbins onto a loom bobbin In a few cases, the yarn was spun directly onto the loom bobbin

When two-ply yarn was made, the old practice was to put two single bobbins on pegs of the twister and run down to a twister bobbin The usual arrangement is to run down two 2-ounce bobbins onto one 4-ounce twister bobbin If the two-ply yarn was used for knitting, it was wound directly from the twister bobbin to the knitting cone or it might be run into a skein and dyed and wound from the skein to the knitting cone Two-ply filling yarn was taken directly from the twister bobbin to the loom bobbin If used for warp, it was usually wound onto a cone and then a number of cones set in a creel and wound onto a forty- or forty-eight-end jackspool, which was put up onto the dressing creel

The introduction of automatic cone winders and automatic quillers, together with a much more economical method of slub dyeing, has brought about a change in these procedures The automatic traveling spindle cone or tube winder (Fig 4) has also affected this routine On the automatic winder one operator can produce three or four times the former amount, hence the winding operation has been brought down to a low cost The trend is toward ring spinning on larger bobbins in order to reduce the winding cost of previous methods Automatic winding however, has brought the winding cost per thousand bobbins so low that it is not necessary to use such large bobbins

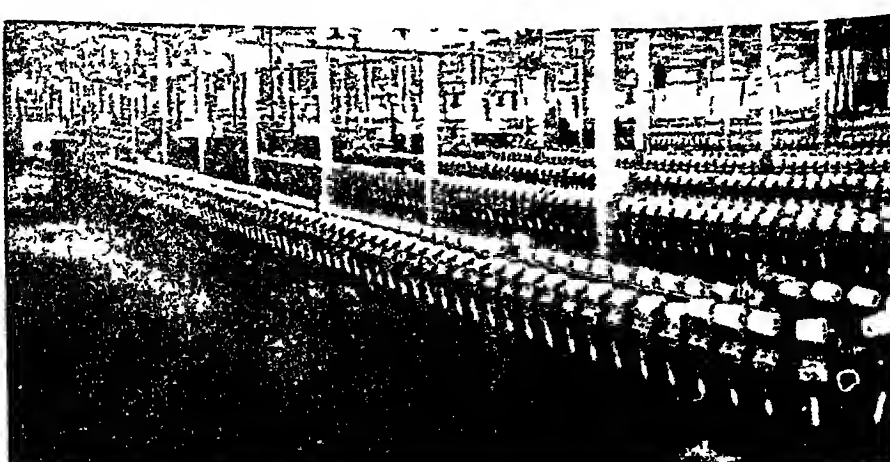

Fig 4 Automatic traveling spindle cone winder (*Courtesy Abbott Machine Co*)

and rings with the consequent loss in spinning speed and poor spinning A good compromise on the factor of spinning cost, doffing cost, and winding cost indicates that a 4-ounce bobbin is the maximum desirable Even a 2-ounce bobbin can be wound so cheaply that the advantage of larger bobbins is unnecessary This applies both to single and two-ply yarns

On these machines, the operator sits or stands at one end, picks the bobbins out of a large supply hopper, drops one into the magazine, and brings the thread close to a suction ring that thereafter holds the thread When the full package comes up to size, it is slipped off the spindle and replaced by an empty It takes very little skill to do this,

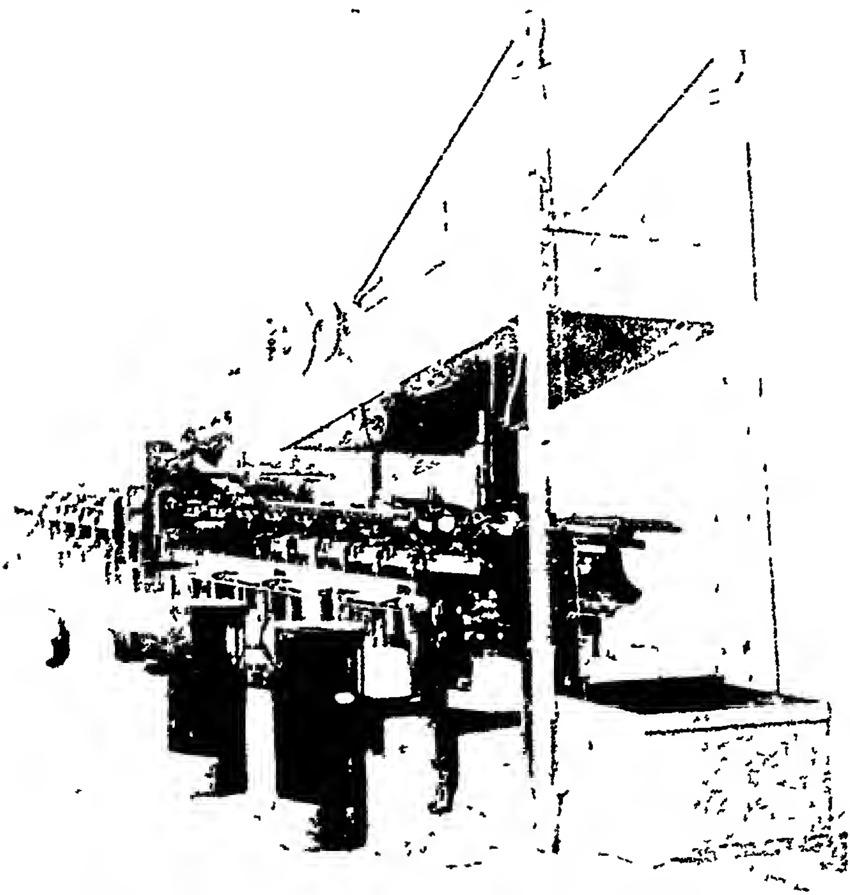

FIG. 5 Automatic quiller (*Courtesy Abbott Machine Co*)

all of the other operations previously done by the operator having been eliminated; putting the bobbin on the peg, finding the end of the package, tying the two together, and threading them into the tension and club catcher are all done automatically

The automatic quiller (Fig 5) runs in a similar fashion The empty quills are first put into a box on the floor and are then hoisted up into a large hopper that can hold 3,000 to 4,000 bobbins Thereafter the quills are picked out of this hopper, arranged in order, and automatically fed down through chutes or slides to a bobbin-changing device that drops out the full-wound quill and inserts an empty quill as the winding units pass by The full quills are delivered into one or, in some cases, where several lots are run, into four different bobbin boxes The only work required of the operator, is to tie in full cheeses or cones as a supply package and to piece up an occasional broken end One quiller of a suitable length to wind one bobbin in one circuit around the machine will produce an average of 1,000 to 1,200 bobbins per hour. It is entirely possible for one operator to run two machines, although where there is much changing of lots and counts, one operator runs only one machine The production is, therefore, at least 1,000 to 2,000 bobbins per hour per operator and, as these quills usually run about 10 per pound, the production per operator will average about 120 pounds an hour running one machine or 240 pounds an hour running two machines. This compares to a production of 250 bobbins an hour run on the former stationary spindle filling winder.

Slubs on worsted yarn are an important factor in winding and vary greatly between different mills, even in the same mill, depending on how clean the yarn is made and how close the slubbing must be made for the particular fabric in mind The slubs to be taken out will run from two to ten per pound, whereas the spinning bobbins, as noted above, will run from four to ten per pound, hence the number of knots tied on the single yarn winders to take out slubs may often be as much or more than the knots tied to tie in fresh bobbins This is always a factor to be taken into account in figuring winder production

Slubbing of worsted yarn has always been a problem The usual practice in former times was to run the two-ply yarn onto a dresser spool at a very slow winding speed and while looking over the sheet of threads, stopping the machine frequently to pluck off or tie up a slub. On two-ply yarn it is desirable to clean the slubs out of the single yarn, tying in a small single knot which need not then be burled out of the goods. With previous methods of winding, this was too expensive a method, but by using automatic winders, the new bobbin can be tied in and the slub can be removed at such a low cost that

preference today must be given to the cleaning of the yarn on the winders The dresser spooling operation can then be eliminated entirely so far as single yarn is concerned Either single or two-ply yarn for filling can be taken directly off the winders and put on the automatic quillers In similar fashion, the two-ply yarn can be taken off the winders and put in over-end creels for high-speed dressing or can be run onto dresser spools at high speed without any inspection.

On the woolen system, much of the new spinning is on the large ring-spun frames, giving about a 12-ounce bobbin, or, in some cases a giant mule-spun bobbin. In either case, it hardly pays to wind the yarn onto packages ahead of warping A magazine tail is left and these large spinning bobbins are put directly in an over-end warping creel On woolen filling yarn in similar fashion the large spinning bobbin can be put directly on the automatic quiller and the loom bobbins wound direct Owing to the relatively small supply packages, an operator runs one quiller, with a production of about 1,000 bobbins per hour.

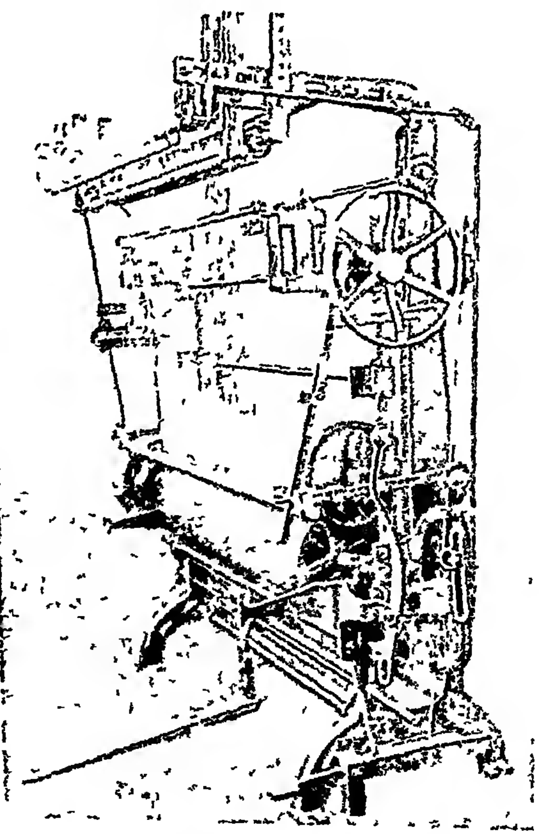

Fig 6 Electric eye jackspooler.

Woolen Yarn Rewinding

Woolen yarns are generally supplied on mule bobbins, since most of the woolen yarns in the United States are spun on mules Woolen yarns are generally rewound for warping from these bobbins to jackspools of forty or forty-eight ends, or both, by a machine known as a warp spooler or jackspooler (Fig 6). If the yarn requires any inspection, this machine gives the opportunity to

break out defective ends, to repair and make knots, and to appraise the yarn as to its quality and uniformity of spin There are a great variety of such spoolers manufactured, which might be listed as follows · high-frame plain spoolers, low-frame plain spoolers; high-speed spoolers, compression spoolers, inspection spoolers, and multiple-drum spoolers These spoolers are individual preferences with weaving-mill superintendents and their selection depends on the individual requirements of each mill They are explained by a prominent builder as follows.

"The terms *high-frame spooler* and *low-frame spooler* indicate whether the yarn travels vertically or horizontally from the supply package in the bobbin stand or creel to the jackspool If the yarn travels to the top of the machine and then down to the jackspool, the machine is a high-frame spooler If the yarn travels horizontally from the supply packages in the bobbin stand or creel to the jackspool, the machine is a low-frame spooler Generally speaking, the low-frame spooler allows the spooler tender to stand closer to the work, both for tying in new supply packages in the bobbin stand or creel, and for finding and tying in ends of the jackspool

"The term *compression spooler* indicates whether a compression roll rests on the yarn of the jackspool to compress the yarn and to build a firm, hard spool containing a long yardage The compression spooler generally is considered better for tender yarns, as it reduces the strain on the ends The plain spooler with weights on the gudgeons of the jackspools is generally preferred for worsted yarns, which make a firmer spool than woolen yarns The compression spooler's chief advantages are in spooling soft, bulky yarns

"*Inspection spoolers*, of course, are machines which serve the double purpose of yarn inspection and putting yarn on jackspools They provide, in addition to the usual spooling arrangements, an area in which yarn imperfections may be noted and removed during the spooling operation This is the logical and most economical place to remove faulty yarn, and the textile industry would benefit from a wider use of inspection spoolers

"The term *multiple-drum spooler* indicates that on this machine more than one jackspool can be made at one time, because more ends can be run and, in spite of lower speed, this machine gives a higher production and at the same time a chance to inspect the yarn For this reason the multiple-drum spooler can be adopted both in woolen mills and worsted mills A warp spooler may be used for yarn that is used later for filling, or for twisting, or even for knitting The yarn may be put on the jackspools only as a convenient and economical

put-up for shipment The five classifications made are the names used generally in the trade to describe the types of spoolers on which parts are used Further subdivisions under these classifications, such as plain compression roll, grooved compression roll, grooved drum, extension drum, quick traverse, high production, or special model spoolers will be self-explanatory"

In the preparation of good warps from woolen yarn spooling plays an important part The whole equipment consists of a jackspooling machine, jack or dresser spools, and a yarn creel or bobbin stand

The winding drum is generally 1 yard in circumference It drives the jackspool by friction The drum is made of wood or metal, and covered with leather, or made out of metal tubing and grooves cut in the surface for cross-winding the threads Machines with a grooved drum do not require a vibrator mechanism

Compression spoolers have a heavy metal roller, of the same width as the jackspool, resting on the yarn as it is wound, for the purpose of compressing it and making a firm, hard spool Compression rollers may be grooved or plain A spooler with a grooved compression roller does not require a vibrator mechanism On the older spoolers a clock is used to indicate the number of yards of yarn wound on a spool This may be a plain clock with worm and worm gear, having a measuring capacity of 3000 yards in one revolution, or a compound clock with auxiliary dial having a measuring capacity of 90,000 yards The newer spoolers have a direct-reading clock, or counter, to indicate the number of yards put on any spool.

A conditioning pan and rollers for moistening yarn, thereby restoring lost moisture, can be used with practically all spoolers and find considerable use on worsted yarns The conditioning pan may be used for putting fugitive tints on yarns for their identification in later processes It is a valuable accessory for this purpose

Stop motions may be of the vibrator or rotary type, or electrically operated They have an individual finger for each thread and stop the machine quickly when an end breaks down Where the automatic brake is used, the stoppage can be regulated to reduce to a minimum the over-running of the spool

The multiple-drum compression and inspection spooler is particularly interesting from a production standpoint and extensively employed in large plants This spooler is particularly valuable for detecting and removing faulty yarn before it is transferred to the jackspools from Franklin packages, cones, or cheeses These machines, which have a production of from 15,000 to 25,000 pounds per week, have reversible metal inspection boards of a contrasting

color on each side Tension is maintained uniformly throughout by a series of porcelain eyes on the creel and a sanded roller for each spool There is a steel compression roller for each spool, operated by a rack and pinion on a common shaft. Guide grooves prevent neighboring threads from overlapping. Drop fingers above the compression rollers serve to stop the machine when an end drops out. Three combs or reeds serve to keep the ends at equal distances allowing perfect inspection of the yarn. A variable-speed drive permits the spooler to start at half speed to avoid yarn breakage due to shock and strain They are manufactured in three types, with grooved compression roller, with plain compression roller and individual thread guides, and without any compression roller (which is used when there is objection to tending the yarns). When frequent changes of the number of ends must be made, the two latter machines are generally used A wetting pan with copper rollers for conditioning or tinting of the warp are also employed Speeds up to 250 yards per minute or higher can be attained on such spoolers

Worsted Beam Warping

Now that the yarns have been properly rewound in the type of put-up desired, beam warping is employed in the various mills wherever sizing (or slashing) of the entire warp is necessary On staple (as well as single) ply and on uncolored (as well as colored) yarns used for warp purposes, beam warping is of decided advantage because of convenience, smaller cost, and greater productivity, as well as better warps On account of the relatively greater strength of worsted yarns this system is generally preferred by large American mills The equipment consists of a large V creel of wooden or metallic construction mounted on casters, that is equipped to hold large warp bobbins (in the French system), cones or cheeses and even wooden-head spools, depending on the yarn supply.

The truck creel is built in sections and will hold upward of 400 to 1,000 individual yarn packages arranged in ten tiers. the end from each is delivered over-end (unrolling is less desirable), then through porcelain guides and, in some of the modern creels, through disk or counterbalanced tension devices forward to the beamer The creel has a V shape with the vertex at the beamer; in some cases a parallel creel is used The single end from each yarn package is brought forward to the beamer and passed through a reed, bringing all ends into the same horizontal plane The reed is an open one in which the total number of ends are distributed over a width corre-

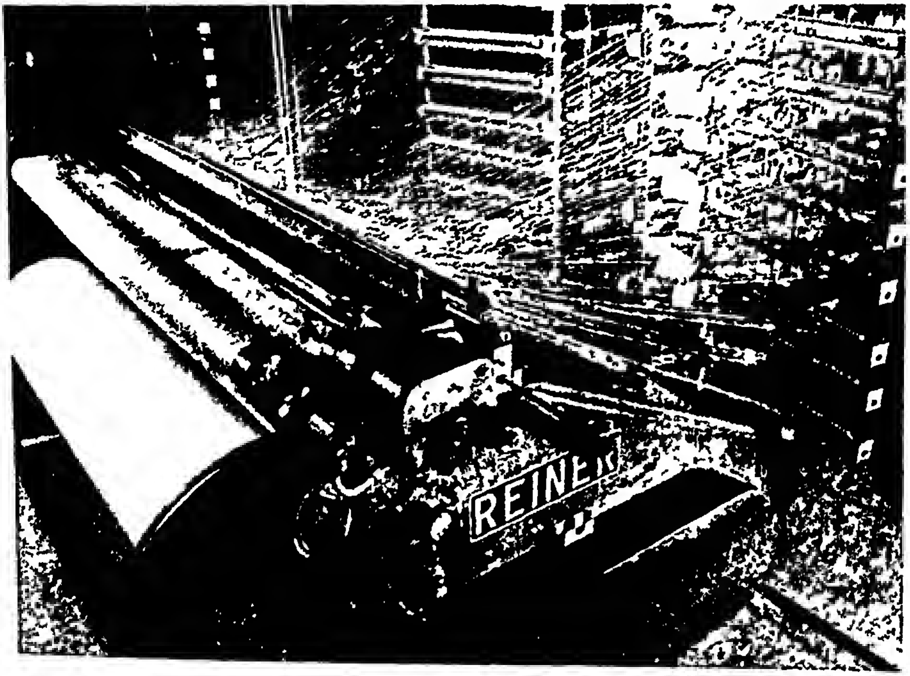

Fig 7 High speed warper (*Courtesy Robert Reiner, Inc*)

sponding to the reed space of the goods to be woven from it, usually 62 to 72 inches or slightly wider

From there it passes as a sheet of yarn under the faller rod which, when spools or rotating packages are used, has a twofold purpose. First, when the warper is stopped, the spools overrun a little and instead of wrapping around the spool or dragging on the floor, the faller or tension rod serves the purpose of taking up the slack and prevents the ends from snarling, especially on high-twist yarn Second, when an end breaks and the warp must be turned back, the faller rod serves to take up the slack Each end then passes over a steel guide rod into a bank of drop wires, one for each end, which falls by its own weight and mechanically or electrically stops the warper when an end breaks or drops out

From the drop wires the ends pass through an expansion comb in which the ends of the entire yarn sheet are spread uniformly across the entire width This type of zigzag comb is adjustable at will (as the ordinary reed is not), hence its name This comb is adjustable in order to permit the yarn sheet to conform exactly to the width of

the beam on which it is wound. Modern beam warpers are equipped throughout with ball bearings, and also with automatic lint cleaners, electric or mercury stop-motion units, and silent chain drives

Beamers can also be provided with a reciprocating motion To build up a beam with a yarn sheet of, say, 800 ends, it is very important that the yarn is wound uniformly across the whole beam, without filling up on one side or slipping off on the other, and so forth The yarn sheet then passes over a roller down to the beam, which is driven by friction with a driving drum about 12 or 18 inches in diameter, on which the warper beam rests as it rotates at a constant speed, irrespective of its diameter.

To avoid too high yarn speeds and consequent yarn strains in warping fine, single yarns, for instance, cone drives or variable-speed drives are used today The object is to retain the same surface or yarn speed at all times, irrespective of the diameter of the beam A slow starting speed is used and also a regular running speed. These devices help greatly to prevent yarn breakage due to sudden strains in starting up

The beams generally are wooden covers or barrels with cast-iron or reinforced adjustable wooden or steel heads about 30 inches in diameter Of late, wooden heads with steel bands around their circumference are preferred by mills with cement floors Invariably cast-iron or steel heads crack or break when these heavy beams, containing anywhere from 3,500 to 6,000 yards of yarn, are removed from the warper As soon as the beam has been filled, it is removed and an empty one started up At a speed of 125 yards per minute it takes anywhere from one hour to one and a half hours to fill a beam of 420 ends, holding 3,500 yards of a 1/25 worsted yarn.

In mills where a great variety of widths are used, such as men's wear and women's wear, a changeable or expansion drum can be used Unless a mill employs several warpers of different widths, it becomes necessary to use expansion drums They can be adjusted to various widths within given limits, of course The necessity for adjustment is readily seen when it is understood that difficulties do arise when warper beams are too wide or too narrow Although changeable drums have many advantages they also have the disadvantages of becoming noisy and of wearing out considerably faster than solid-steel, felt-covered drums

Girls are usually employed, on a piecework basis, to do warping inspection They are required to inspect the yarn as it is being warped and to remove faulty or defective ends by replacing them with perfect yarn from single-supply spools usually strung or suspended

across the top of the warper. Hence, speeds used are generally moderate to permit this work to be done thoroughly. The operator stands in front of the warper, usually with her back to a window to give the best lighting possible, if overhead or saw-tooth lighting is not available. An experienced warper operator can warp about 28,000 yards in an eight-hour day on 1/25s worsted yarn, 420 ends to the beam Such a warper beam would weigh close to 150 pounds, and beam doffing devices provide for easy doffing of these heavy beams Warpers are generally arranged in groups facing windows and driven by a group drive or by individual motors. In dry weather or on cold, windy days, modern mills have humidifiers operating to keep the surrounding air humid and to allay the static electricity that is created by worsted yarns when passing over friction areas A relative humidity of 50 to 60 per cent is generally recommended.

Of late, in the woolen system the beam warper has found application in conjunction with the high-speed dresser reel and also with a magazine cone creel In such an installation it becomes necessary to use an electrical control unit which will divert the power from the warper to the reel and, whatever operation is being run, the electric stop motion and lint cleaner on the machine will function This arrangement really consists of two separate machines: a machine for reeling and a machine for making worsted warps on section beams There are decided advantages to this arrangement such as greater flexibility and production, better warps and weaving conditions

Worsted Warp Slashing or Sizing

When a sufficient number of beams of a given number of worsted yarns have been warped, they are stored on the floor in readiness for the slasher, behind which a number of them are combined to make up the total number of ends required in any warp. On account of their great weight they are generally stacked or creeled horizontally, although with lighter beams they can be creeled vertically While the upright beam creel saves floor space, it requires overhead cranes and pulleys to lift the beams into place The common method is to stack them horizontally as shown in Fig 10 The backbeams, as they are called in American practice, in one set should be of the same width and should all correspond to the width of the loom beam, on which they are wound after slashing and drying When there is a difference in the width of the individual backbeam, the widest beam is generally placed nearest the slasher and the narrowest toward the end of the row of backbeams

Object of slashing Woolen and worsted yarns are sized or slashed with the object of laying all the surface fibers on the yarn, making the yarn more compact and smoother, while also strengthening it, so that it is better able to withstand the chafing and rubbing action of the heddles, harnesses and reed in the loom This does not mean that all woolen and worsted yarn need to be slashed, but with automatic, high-speed looms coming into more common use, it will be more than ever necessary to slash warps In this connection it might be said that fine single worsted and woolen yarns are sized at the present time A yarn of long wools is less likely to require sizing than one made from short wools Nevertheless, yarns made from crossbred wools often develop hairiness and much surface fiber, especially if spun on the Bradford system or cap spun, so that slashing becomes necessary for such reasons alone In addition, yarns generally snarl and entangle in the loom causing ends down If a yarn is very uneven or weak, as is the case with many woolen yarns, sizing is invariably necessary Then again, twist must be taken into consideration Up to a certain point, twist will strengthen a yarn, but after that peak is reached it loses in strength considerably. When twist does not serve the purpose or is undesirable, the yarn has to be sized Ply yarns or heavy soft-twisted yarns, while not generally sized, are sized when they go into fabrics closely set in the warp (or "heavily sleyed," as some designers call it) Also where the goods are designed to take a high pickage in the direction of the filling, it becomes imperative to size thoroughly even with favorable warp yarn or weaving conditions

The process is of considerable importance since much depends on the slashing of worsted and woolen warps and the benefits to be derived in the weaving of such warps Hence, skilled man-labor is required in this department as well as equipment flexible enough to satisfy all the needs of the weave room Because woolen and worsted yarns develop static when subjected to friction during weaving, sizing often serves to condition the yarn, i e, to supply sufficient moisture to set all twists and to prevent the yarn from going to the weave room in too dry a condition If yarn is too dry during weaving, it becomes too lively and consequently, snarling or bunching result

Operation of the slasher. Worsted-warp slashers or sizing machines are of two types. (1) drum or cylinder slasher; (2) drying chamber or hot-air slasher Both are in use in American mills, and, of the two, the hot-air slasher is probably the more commonly employed in worsted-warp slashing The machines generally consist of a size box with immersion rollers, a drying chamber or series of can

dryers, split rods, and a beamer, which produces the weaver's beam, ready for the loom.

After the necessary number of back beams from the warper have been assembled in their proper places in the beam stands, the yarn sheets from each beam, by passing under and over one another, are combined into one single sheet. Some mills put this sheet of yarn through a reed or comb to bring it to the actual width required as well as to spread or space the yarn evenly across this width In this form the sheet is taken beneath one or two pair of copper immersion rollers, which operate in the heated size solution of a size box. From the size box it passes through a pair of squeeze rollers, generally made of rubber, which serve to rid the yarn of excess size solution Flannel coverings that are used on the rollers to reduce the sharpness of the nip must not be allowed to become glazed or hard, which would have the undesirable tendency of flattening the yarn The yarn now passes through a drying chamber or over a small and a large drying cylinder in the manner shown in Fig 8

These cylinders serve the purpose of drying the sized yarn sheet as rapidly as possible It is generally found advisable to use two cylinders, as the speed of slashing depends upon the ability of the ma-

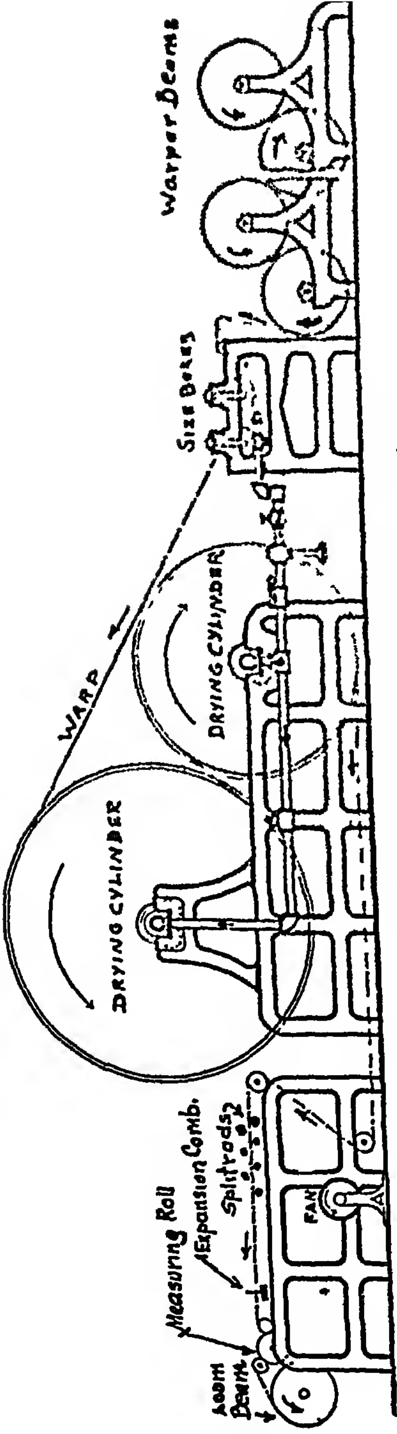

Fig 8 Common arrangement of modern slashing equipment.

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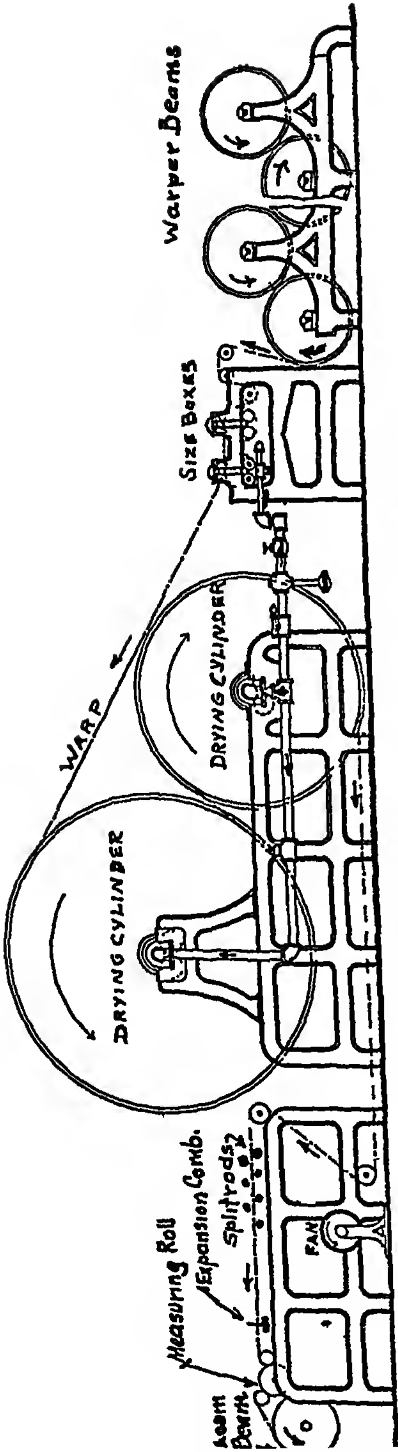

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dryers, split rods, and a beamer, which produces the weaver's beam, ready for the loom

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terial to be dried rapidly When a drying chamber is used the warp passes back and forth over heated steam pipes in a glass or metal enclosure 10 to 12 feet in length Space is the deciding factor in the choice of the slasher used Steam gauges, reduced valves and, in some cases, temperature controllers are employed to regulate and obtain the greatest efficiency in drying A pressure of 4 to 9 pounds of steam is maintained in the cylinders Some mills employ fans in the drying chamber and under the cylinder machine to aid in the drying and cooling of the warp yarns after they leave the heating elements Naturally, the more ends there are in the warp or the heavier the size on the yarns the slower the drying and the production in sizing

The sheet of yarn now reaches the split or separating rods and the measuring roller The purpose of the split rods is to separate or divide the individual sized warp yarns that adhere or cling firmly to each other after drying Numerous smooth rods are used here, depending on the degree of sizing done, the number being largely left to the discretion and judgment of the operator Usually he uses one less than there are back beams in the set In well-managed mills the round steel rods vary in diameter, the larger diameter rods being placed first and nearest the cylinder or heating chamber An expansion comb, similar to that used in the warper, completes the separation of the ends and provides for delivery of a yarn sheet of the exact width that is required in the loom The yarn then passes over a solid iron roller and around a larger tension roller and over a second solid iron roller down onto the loom or weaver's beam The tension roller serves to add tension to the yarn at this point in order to build a solid and compact loom beam By wrapping layers of cloth around the large tension roller, the tension on the warp can be increased or decreased at will

The purpose of the measuring roller is to measure the length and actuate a dabber or brush, which is dipped into a liquid tint of aniline dye and marks the warp every 60 yards or so This serves to indicate to the weaver when a piece or "cut" is coming to an end, at the point where he is to cut the woven fabric across the width The marker is connected with a measuring dial or clock, also with a bell gear that actuates a bell indicating to the slasher operator the number of pieces or cut lengths that have been put on the weaver's beam

The beamer, as this end of the slasher is termed, is driven by friction to enable the tender to apply tension as is deemed necessary, as well as to compensate for the constantly increasing diameter of the

beam This tension allows the winding of the sized yarn sheet to proceed at equal surface speeds as it is given up by the draw roller onto the beam, which is provided with cast-iron or wooden reinforced heads The draw roller is driven positively and is connected by a long shaft with the squeeze rollers In this manner undue tension on the yarn is avoided A slow-speed drive is provided to permit the cutting off of laps that form around the back beams or at the squeeze rollers, and to permit the fixing of broken ends and the insertion of dividing rods at the start of a new beam

A compression roller is used where solid and full loom beams are desired It is quite often desirable to get as much yardage on these beams as possible Also, to get a uniformly built warp which is level and perfectly round, a compressor is necessary This press roller is usually placed below the beam and is supported by two lever arms on which weights are placed in accordance with the pressure desired

Importance of sizing The sizing or dressing compound and its composition is an important factor and much depends on its proper ingredients, preparation and temperature during composition Here a knowledge of the different fabrics, yarn characteristics, and of sizing ingredients is essential

Size is not always applied to woolen and worsted yarns Some mills rarely make use of any sizing compound whatsoever, claiming that the presence of size is the cause of various troubles in finishing and dyeing These claims are not true when the size solution is properly made There can be no doubt that the application of size is beneficial and actually necessary for single warp yarns in order to give them the strength required for weaving

The constant chafing of the yarn in passing through the heddles on the harnesses tends to wear, weaken, and break the yarn In working forward and backward to beat up the filling the reed chafes the yarn even more than the harnesses On fuzzy yarns the reed will scrape the loose fibers from each thread and collect them in balls behind the reed and in front of the harnesses When these balls or bunches grow large enough through the constant accumulation of loose fibers and the warp is passed forward by the take-up, the yarn will be unable to pass through the reed and will break

It is therefore the object of sizing to apply a mixture to the yarn that will glue these loose fibers to the body of the yarn, thus increasing the power of the yarn to resist chafing and increasing its strength

Although one warp may be used for several different fabrics, both men's and women's wear, it is impossible and impractical to change the size formula in every instance and for every different purpose

The sley or set of a cloth, how it is to be finished, what weaves are used, the number of picks to be inserted, the reeding of the warp the use of a false reed, and other factors play a large part

Sizing equipment and ingredients The equipment necessary for the preparation of the size are several 115- to 150-gallon mixing kettles, stirrers or mixing agitators, pails and storage space for the size compounds and ingredients, and a steam and hot-water supply as well as a pump, if the size is to be piped directly to the slashers In large mills a separate room is assigned to this work The size kettles are preferably steam-jacketed as the mixture of size is usually boiled and agitated for extended periods. Some mills use closed kettles and boil the size with direct steam under pressure

Three grades of sizing on worsted yarns are generally recognized in American mills They are light, medium, and heavy The light size solutions serve where no strength is to be added to the yarn and only a light laying of the surface fibers is required The medium size is probably the most common on worsted warps because it serves most purposes for which worsted warps are employed *In the preparation of all size solutions it is important to bear in mind that the sizes used on woolen and worsted warps for men's wear and women's wear (especially piece dyes) must be capable of being completely removed in the scouring of the goods in finishing*

There is still much secrecy and groping in the dark about what ingredients give the best results in sizing For woolen and worsted sizing there are only three essential types necessary, namely,

1 Adhesive substances
2 Antiseptic agents.
3 Deliquescent substances

1 Adhesive agents. The adhesive agents are the most important and are actually the basic agents of sizing The oldest substance employed for sizing is animal glue The highest grade of hide glue in flake form is soaked for several hours in water, after which it is dissolved in boiling water For a very strong size on fine woolen yarns 8 per cent glue solution, approximately 2 pounds to 3 gallons of water, is suitable.

Because of the high price of the glue, various starches have found wide application as excellent sizing compounds For highest requirements the starches are still fortified with glue The most frequently used starches are corn starch, tapioca, and potato starch Corn starch is the most commonly used, but tapioca is a strong competitor because of its lower coagulation point. In making up the size, the starches are converted through a boiling process into a viscous solu-

tion These solutions, when of high concentration, will coagulate when the temperature falls below a certain point For example, a 10 per cent corn starch solution will start to solidify when the temperature drops below 130° F, whereas tapioca with the same concentration will not solidify until the temperature drops below 100° F

In addition to the three starches mentioned above, modified or thin boiling starches, dextrines, or gums are often added to a size solution They increase adhesiveness, but increase the cost also The most economical way of preparing thin boiling starches is by converting the regular starches with the help of converting agents such as alkalies, acids, diastase, and other compounds on the market. The most common is para toluene sulfonchloramide, an organic chlorine compound which converts the starch into a thin boiling form at boiling temperature, through the action of the chlorine present The conversion of starch by means of diastase is more difficult as it has to be done at a certain temperature below the boiling point and the conversion is very easily overdone to the formation of starch sugar with no adhesive power whatever The advantages of these modified starches are that the size produced is slow-congealing and very adhesive, thus yielding a smooth and well-sized yarn

2 Antiseptic agents The addition of antiseptic agents is very helpful and these substances should be made a part of every size formula With perfectly dry warps there is no danger of mildew, but as soon as the warp gets damp or wet, danger of mildew is present The presence of a fungicide eliminates the danger of mildew, which may result in serious damage to the wool fibers Antiseptics suitable as preventives of mildew are thymol, resorcinol, beta naphthol, boric acid, zinc chloride, copper sulfate, salicylic acid, and other compounds known by trade names Three to 6 ounces of any of these to each hundred pounds of starch is sufficient, except with boric acid where 20 ounces are needed

3 Deliquescent substances Deliquescent substances such as glycerin may be beneficial in certain sections of the country, where the climate is very dry, but caution must be exercised in using them in damp climates In woolen and worsted sizing, softening agents have little use, because of the character of the wool fiber When necessary, a little peanut oil may be applied at the loom by running the warp threads over a pad that has been soaked in it.

Fugitive dyes or tints are added to the size solutions also to identify warp yarns of different twists such as S and Z in crepes and coatings

Chain warping and the old form of upright hand warping (as in Bradford mills) are no longer employed in American mills

The warping of woolen yarns for woolen goods of all descriptions and weights is generally done by the horizontal dressing frame or backstand In this system the yarn is generally supplied on jackspools of 40 or 48 ends, and combined to form sections of 560 to 670 ends, in which each thread has its proper place and each is parallel to the others These sections are arranged side by side on a large reel until the whole warp is completed This operation is known as *dry warping* Whenever necessary, the sections can be sized or dressed by threading them through the size pan and dresser (which is really a dryer) and the necessary rollers and reeds

The whole arrangement consists of a spool stand, or creel, a dresser made up of an entering reed, size pan with one or two pairs of submersion rollers, and a drying frame, a section reed on a stand, a large reel and a beamer The whole apparatus may extend over a space 23 to 30 feet in length and about 11 to 12 feet in width The setup shown in Fig 9 is common in American woolen mills

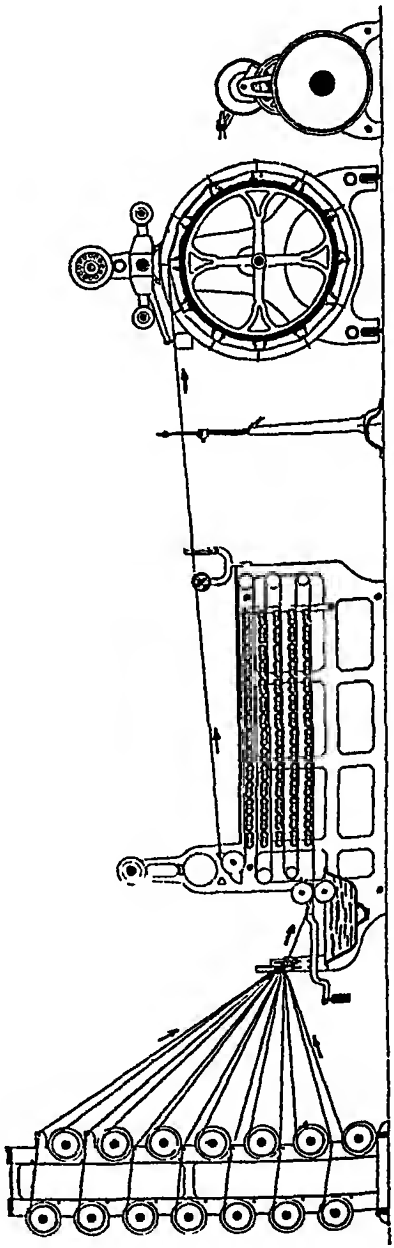


Fig 9 Setup for woolen warp dressing

Creel or jackspool stand The jackspools, as received from the spinner or prepared in the spooling department of the weaving mill

(as described under worsted warping) are placed in the creel or spool rack, which is made of steel or wood and can take from 32- to 40-inch spools up to 12 inches in diameter, in the same set Weights, which are easily adjusted and cannot drop off, are used to apply tension to the spools during warping A creel may hold from two to eighteen jackspools, comprising up to 864 ends in all Creels are made in plain and adjustable types

Entering reed and size pan. If the warp is not to be sized, a hack stand or dry dresser, which is really a skeleton dresser frame, is used It includes holders for the gathering or entering reed, the lease reed, a measuring roll, a yarn vibrator, and a clock. A separate stand and holder is provided for the neck or section reed that condenses the yarn into its proper section width before it is wound on the reel The hack stand is not generally driven Rollers turn with the yarn as it is drawn through the hack stand by the large reel

When a warp is to be sized, the yarn of a section is passed through the entering or tying-in reed into the nip of the pair of squeeze rollers, the lower one being made of copper and termed the immersion roll, and the upper one being made of rubber covered with cloth With yarns that need sizing to a high degree, it is necessary to submerge the yarn in the size solution by means of depressing rollers before it passes through the squeeze rollers

The size pan is steam-jacketed to keep the solution warm The yarn is now squeezed out to remove excess size and then passed directly into the steam dresser or dryer Here, the narrow yarn sheet passes the entire length of the chamber, which has rows of steam coils in horizontal tiers to supply the heat for drying The yarn sheet in the dryer passes back and forth over the skeleton rollers from four to six times according to its ability to dry, and then forward over a guide roller or measuring roller to the neck or section reed In place of steam coils, there are also so-called one- and two-cylinder dressers where heated cylinders or cans are used in place of the steam pipes These serve well on yarns that are sized only lightly, whereas the steam-coil system is more adapted to all-purpose sizing of woolen yarns

From the measuring roller on top of the dresser, the yarn passes through the lease reed on top of the dresser This reed is a blocked reed, one dent empty, one blocked, i e , one-third of the dent is closed at the top and one-third at the bottom, leaving the final third open in the center Alternate dents are treated in this way One end passes through the open dent and one through the blocked dent Ahead of

the lease reed is found the condenser or section reed, called by some the *neck reed,* which serves to condense the ends to the width of the section intended for the reel The total ends in a warp section are divided equally in this section reed For instance, if there are 600 ends in a section and the reed is a number ten (having ten dents per inch) and the section is to be 6 inches wide, ten ends must be placed into each dent Uniform and equal denting is important here or the section will not build well on the large reel

How to take a lease Since each section at the beginning, middle, and end of its length on the reel should have a lease, it becomes necessary to insert leases at these points during the making of a warp This is done as follows The whole section of yarn is cut, knotted, and hooked on the reel at the space where the section is to be laid on the reel It is taken in front of the section reed by means of two wooden lease rods With one rod, the ends near the reed are pressed down This causes the ends in the open dents of the lease reed to go below those in the blocked dents Into this shed or opening is inserted a rod, lease string, or cord Now the yarn is lifted up with the lease rod so that the ends which were at the bottom will be at the top A rod is passed through the opening and opened out The other half of the cord is passed through this opening or shed and the two loose ends of the cord are tied together This constitutes an "end and end," or single lease When this is done, the measuring clock is set and the directly driven reel started up

The warp reel The modern reel is a high-speed reel that may be of the brass-plate-with-pins or of the pinless type The cylinder body of the reel is 4 yards in circumference (or even 5 yards) and is formed by twelve cross bars or girts, on each of which, touching the warp yarns, is a solid brass plate with four rows of holes, spaced ⅛ inch adjustment. The pin is No 4 gauge wire and 6 inches long, 4⅞ inches is straight with 1½ inches bent slightly at the top The reel is driven by means of a top shaft and by two pulleys and belts on each end The driving pulley on the top shaft is so arranged that it can be slid along the entire length according to the position of the reel with respect to the section being made A brake is provided on one or both sides of the reel and is used when beaming off the warp To hold the reel in its position while a section is being warped, a foot brake is provided on the casters Track wheels serve to move the whole reel into proper position for the making of each section Two grooved and two flat-faced wheels are provided for this purpose Ball bearings in the truck wheels allow the large reel to move very readily A measuring clock that is attached on the end of the reel

shaft consists of a single worm and seventy-eight tooth gear. One revolution of the reel, usually equivalent to 4 yards, turns the gear one tooth, and one revolution of the clock gear represents 312 yards Although the clock does not measure accurately the length of the section, it serves to get all of the sections the same length The actual measuring of the warp is done by the clock on the dresser, which is more accurate It requires about ½ horsepower to operate the reel, depending, of course, on the speed, the size of the section, and the length of warp made

Of late years, the pinless reel has gained in favor for obvious reasons It eliminates the objectionable pins and section marks on fine woolen yarns There is a marked saving in time due to the absence of pins One form of this reel is known as the Rindge (high-speed) reel Coning device plates are used to build up the first section wound on the reel

Beaming. When the sections have been placed side by side and are of equal length on the reel, the leases inserted and properly tied up, and the whole warp of the proper number of ends and width has been made, it becomes necessary to transfer this warp from the reel to the loom beam For that purpose a beamer (Fig 10) is used

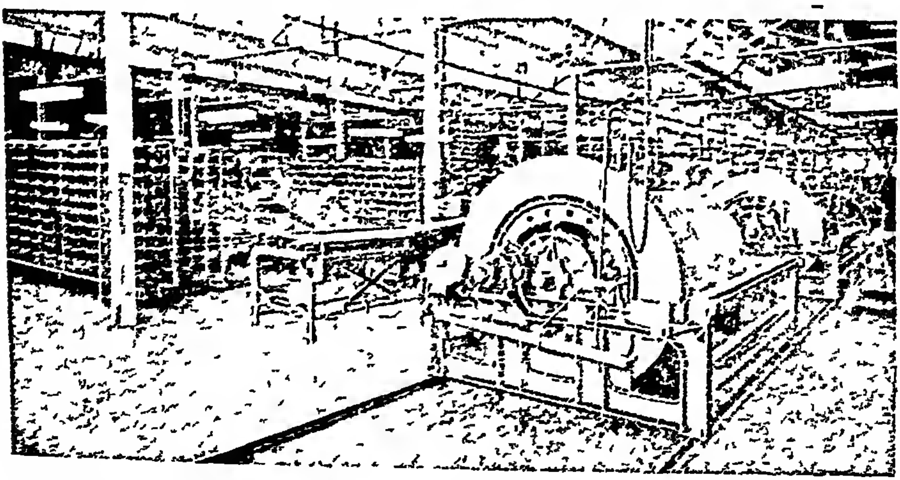


Fig 10 Over-end unwinding from large woolen spinning frame bobbins in high speed warping or dressing *Courtesy· Davis and Furber Machine Co*

Here, the standard single-speed beamer or the heavy type special beamer or the three-speed beamer can be used Belt drive or direct motor drive can be used on the beamer To beam a warp off the reel,

belts are loosened around the reel and friction is added on the warp reel The ends of each section are tied in a group to a leader or cords on the loom beam The quantity of yarn tied to the loom beam should be kept small, so that the knot does not get too large The heads on the loom beam must be adjusted to the required width and the loom fastened in the beamer The beamer is now started up and the tension on the warp adjusted by adding friction to the reel according to requirements In order to make a solid loom beam, a duplex warp compressor is employed The compressor assists in putting more yarn on a loom beam and in making a harder and better beam The pressure is equalized on both sides of the beam and strain is taken off the gudgeons and the yarn The method is the same as in worsted warping The press roller permits from 20 to 60 per cent more warp on the loom beam Compressed warps usually weave better and the yarn retains its elasticity, resulting in better finished merchandise

The making of a warp In order to understand more readily how plain or complicated warps are made with this equipment and layout, it is well to assume an actual plain warp of three cuts 72 yards each There are 2400 ends of ground with 20 ends of selvage on each side which give 56 inches width on the loom beam between heads

The first step is to determine how many spools will be required for one section Assuming the creel holds 12 spools and there are 40 end spools to be used, the maximum number of ends would be 12 x 40 or 480 ends in a section For 2,400 ends in the warp with 480 ends to a section, five sections would be needed Next, the length of yarn to be placed on each jackspool must be ascertained Since the warp is to contain three 72-yard cuts or 216 yards and five sections are to be made, each spool should contain 5 x 216 or 1 080 yards altogether To allow for tying in of the next warp a few additional yards should be made After each of the 12 spools of 1 085 yards each have been prepared, they are placed in the jackspool stand or creel They are now required to be tied onto the yarn that was left in the dresser from a preceding warp To accomplish this. 480 ends are counted off in front of the tying-in reed, and the remainder tied up Then, starting at one end of the reed, the first end is cast up over the top of the reed, end eleven is skipped, and so on until 40 ends have been cast up These are tied together and represent the ends to which the ends on spool number one are tied Then proceed in the same manner to get the ends for the other eleven spools as follows:

For the second spool, pick one and skip ten.
For the third spool, pick one and skip nine.
For the fourth spool, pick one and skip eight
For the fifth spool, pick one and skip seven
For the sixth spool, pick one and skip six
For the seventh spool, pick one and skip five
For the eighth spool, pick one and skip four.
For the ninth spool, pick one and skip three
For the tenth spool, pick one and skip two
For the eleventh spool, pick one and skip one

For the twelfth spool the remaining ends are taken Each group of ends should now be tied to its respective spool, beginning with number twelve spool The last group of ends picked in the reed is tied to the corresponding ends of the twelfth spool, end for end The next group of ends is tied to the end of the eleventh spool and so on until all the ends of the spools are tied up to the ends threaded through the reed and dresser Care must be exercised that no ends are crossed or tied up to the wrong spool The ends may be tied either by twisting-in or by using knots When completed, only the friction boards are placed on the spools, and the warp yarn is drawn through the dresser, carefully and slowly, from the front of the machine Care must be exercised when left-twist is tied to right-twist yarn or vice versa The yarn is then drawn through the lease reed.

The next step is to determine the width of the section in the neck section or condenser reed Since the warp is to be beamed at 56 inches and there are five sections, each section requires 11 inches and 1 inch for selvage (½ inch on each end) If a number 10 neck reed was being used, there would be ten dents per inch and in 11 inches of a section, there would be available 10 x 11 or a total of 110 dents for the section Dividing the total ends in the section by the available dents per section, i e, 480 divided by 110, would be 4 ends per dent and 40 ends left over. These 40 ends will have to be divided among the 110 dents This can be done by taking 70 dents with 4 in a dent and 40 with 5 in a dent, making a total of 70 dents with 4 per dent=280 ends plus 40 dents with 5 per dent=480 total ends in 110 dents.

When the first section is made, 20 ends on each side are added from extra supply spools or bobbins from the dresser for selvage They may be made with the same or different yarns and should also be drawn through the neck reed in this manner reed is a number ten, 20 ends in 5 dents equals 4 ends per dent The total ends for

section one including selvage are now tied to the center of the space on the reel for the first section A lease is put into the warp and the angle irons on a pinless reel are adjusted to suit, and on a pin reel the pins are inserted to mark off the space the first section is to occupy The reel on its track is then placed into exact position with the neck reed The counter clock and bell on the reel is set for the desired length of the warp to be wound on the reel, in this case three cuts of 72 yards each equals 216 yards length Another lease is put in at the middle of the warp (at about 108 yards) and at the end (or a yard or so from the end) of the warp The first section being completed, the ends are tied to the reel in a loop or half-knot

The second section is built in exactly the same manner as well as the remainder of the five sections To the last section, of course, a selvage of 20 ends must be added During the operation of warping, care must be taken that no ends drop or break out and that each section has the required quota If the size pan and dresser are used and the reel must be stopped for any length of time, the steam in the dresser should be shut off, so that the warp yarn is not baked unnecessarily Usually two operators are required on this work As each section is completed the reel is moved into its new position and pins inserted, the clock set and so on

When the whole warp is completed it is ready for beaming

Warping of Fancy Patterns

Whenever a stripe, colored check or plaid pattern is to be warped, the process becomes more complicated and requires planning and calculating before proceeding A typical example is given here to clarify the procedure A warp of 1,944 ends with the following color pattern is wanted:

Pattern	Black	4				=	4
	Blue		2		2	=	4
	Red			1		=	1
							9 ends in one pattern

Twenty-four black selvage ends are to be added on each side and the warp is 65 yards in length The first thing to calculate is the number of patterns in each section 1,944 — 9 = 216 patterns in the entire warp Nine sections here would give an equal number of patterns in each section, i e, 216 — 9 = 24 patterns in each section The total number of ends is also within the capacity of the creel This is the best choice The next step is to determine the number of spools of each color required To find the total number of ends of

each color required in a section, multiply the ends of each color by the number of patterns in a section.

Four black in each pattern by 24 patterns in a section gives 96 total black ends in a section, this requires two spools of 40 ends each and one spool of 16 ends.

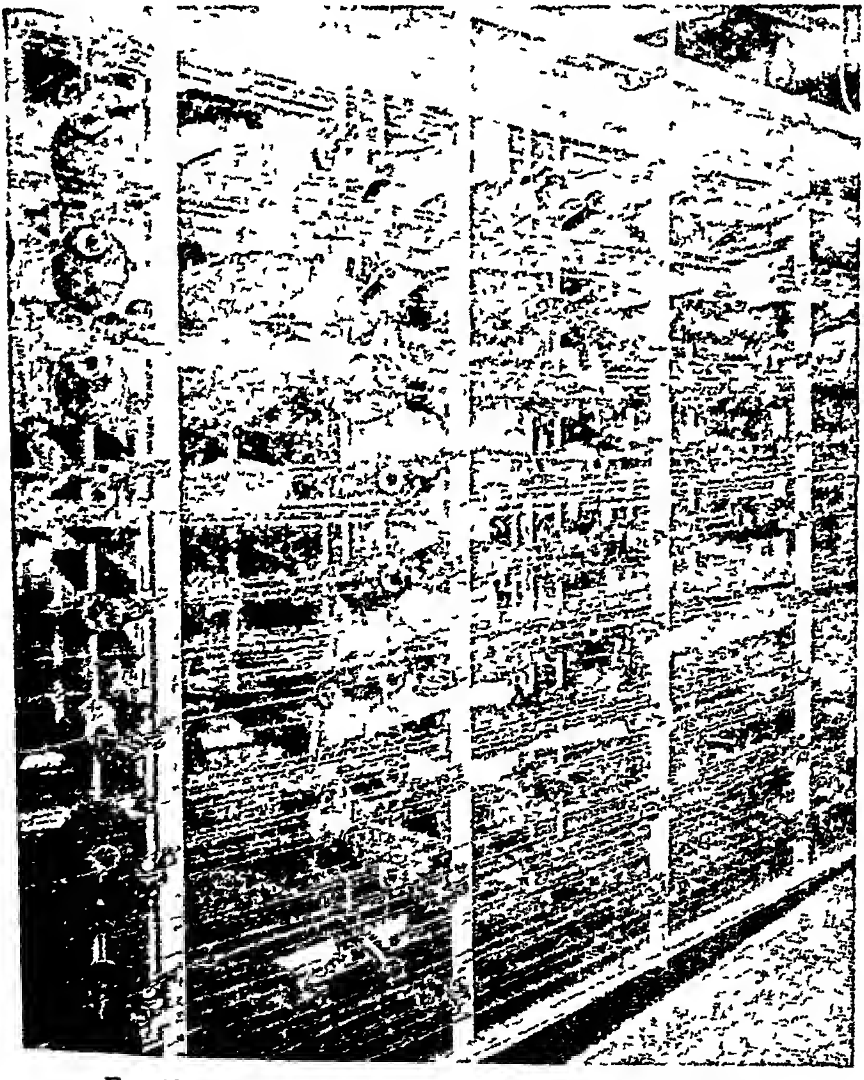


Fig 11 Modern magazine warp creel for large packages (*Courtesy Whitin Machine Works*)

Four blue in each pattern by 24 patterns in a section gives 96 total blue ends in a section, this requires two spools of 40 ends each and one spool of 16 ends

One red in each pattern by 24 patterns in a section gives 24 total red ends in a section, this requires one spool of 24 ends.

The pattern described requires two full black spools, two full blue spools, and one spool with 24 red ends One spool is made with 16 black and 16 blue ends, making a total of six spools for the creel stand A separate spool of 48 ends black for the selvage is made

The total yardage on each spool is 9 sections x 65 yards (warp length) equaling 585 yards plus an allowance of 10 yards for waste at the end of each section, tying in the patterns, drawing in the warp, possible slippage of the spool while spooling, etc This makes a total of 595 yards per spool on all spools The spools are now placed in the jackspool stand or creel in the following sequence from bottom to top: 2 black spools, spaced spool next, 2 blue spools, and then the red spool

Picking the pattern The most common method used in picking the pattern in the entering reed is to drop all the ends in the reed to the bottom Commence at the right and count off the ends required by the pattern The black spools are at the bottom, the blue next, and the red next The number of ends for the red will be taken up first Beginning at the right count 2 ends, which remain down, then lift 1 end for red, place it over the top of the reed, then count 2 for blue, 4 black and repeat the pattern again, 2 blue and together they will make 8 ends Lift one over the reed, count 8, lift one over the reed, and so on until the number for the red are picked out and laid over the reed Tie them together and lay them back over the reed Now count the blue ends, 2 and 2 making 4, place them over the reed, leave 4 down for the black, pass 4 over the reed, leave 4 down, and so on to the end Tie them together and leave them over the top of the reed All the ends remaining down now are for the black Count them to be sure that there is no mistake

After completing this, the ends of each group are counted off in sets of forties and tied, wherever more than two or three spools are used for a color Pull down the first forty for the black, tie them to the bottom spool, then the second forty to the second spool, and so on After all the black ends are tied to their spools, follow with the blue and the red The ends must not cross from one layer into the next, as that will cause tangling and breaking of the yarns With a spaced spool that has two or three threads of one color side by side

and one of another, take no notice of the single end on this spool when piecing the first bunch of ends of that color Start at the bottom spool of the same color until sufficient ends have been tied in the reed for the single thread to run straight, or as nearly straight as possible This will save considerable trouble There are optional methods that can be used here, depending upon the operator's preference

After all sections are made as described previously and the warp is beamed, it is ready to be drawn into the harnesses

Drawing In of Warps

After a warp has been properly prepared in the manner just explained it goes to the drawing-in department, where it is drawn through the heddles of the harnesses in accordance with a drawing-in draft that is prepared by the designer or design department This applies to warps that go into plain, dobby, or head-motion looms, where more than four harnesses are employed On less than four harnesses, twisting-in machines can be employed

Before going into the details of the drawing-in process, it becomes necessary to understand why warps for different fabrics and weaves must be drawn into the harnesses differently How a warp is drawn through the harnesses depends on at least four important factors:

1. The kind of weave to be used
2. The sley or number of ends per inch.
3. The minimum number of harnesses required
4. The kind of yarn employed in the warp

Much depends on this operation and the care with which this operation is carried out This department usually is in charge of a woman who is responsible to the overseer of weaving The department concerns itself with the care and upkeep of harness frames, heddles, and reeds The care, upkeep, and storage of unused equipment as well as of that in use is of utmost importance in the production of high-quality and well-woven woolen and worsted fabrics The finer the yarns, the higher the sley, and the more difficult the weave, particularly on bobbin-changing, high-speed looms, the more care must be used in this department Hence, it becomes necessary that the equipment is the best available and kept in good working order according to the best practice and knowledge

Harness frame The harness frame usually consists of a wooden frame that is rigid in construction and yet light in weight The top and bottom crosspieces are made of knotless, seasoned wood held in

parallel position by metallic or wooden braces Provision is made for tempered, hard steel slide rods extending parallel to the wooden crosspieces and ending in the two metallic braces at top and bottom of the harnesses For wide goods double slide hook are employed at regular intervals, but for ordinary goods a regular frame with studs and lock hooks is used The double sidehooks serve to hold the heddles and give them perfect freedom and sliding ability sideways These harness frames should be kept in good condition by varnishing them from time to time Perfect smoothness is essential to their operation in the loom Heddle rods should be kept smooth by a little tallow, and should be inspected at regular intervals They should be kept clean and free from lint and oil The harnesses are usually stored in accordance with their width and depth and a record is kept of the number of each type available. A number of new spares of each size should be kept in stock The sizes (i e, the width) of woolen and worsted harness frames vary from 70 to 90 inches (woolen and worsted fabrics), from 30 to 200 inches (carpets), and from 90 to 500 inches (felts)

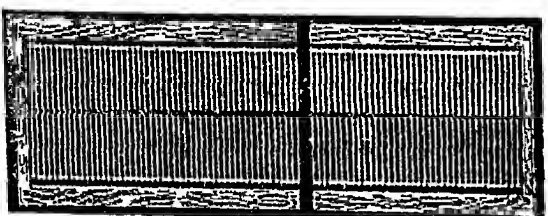


Fig 12 Sectional view of a harness
(*Courtesy Steel Heddle Mfg Co*)

When a new set of harnesses is selected or made up the following data must be at hand (1) width of the harness frame in inches, (2) depth of the harness required in inches, (3) number of harnesses required, and (4) type of heddle to be used

It is generally not considered good policy to mix the harness frames of different makers because of different construction and rigidity Owing to the wide widths of these harness frames, a check on rigidity is important Whenever the solidity or rigidity of a harness frame is impaired it should be repaired or replaced with a new set The old type of cotton harness is not used in the woolen and worsted weaving trade in the United States.

Heddles The types of heddles employed in the woolen and worsted weaving trade are the twin wire with a V eye and the flat steel heddle with an oval eye Cotton or linen twine heddles with metallic mail or eye are not used at all Their only use would be found in Jacquard or carpet looms The twisted round wire heddle is no longer the most common heddle employed in woolen goods weaving For fine

worsteds the flat-steel, super-polished heddle has found considerable application and preference They are classified in the following manner:

FLAT STEEL AND OTHER TYPES OF HEDDLES

	Size of Eye	*Use*
Made	$\frac{5}{16}$ in to $\frac{3}{16}$ in	Woolen and worsted goods
in all	Braised	Felt
lengths	Braised	Carpets

Fig 13 Types of steel heddles and eyes
(*Courtesy Steel Heddle Mfg Co*)

The heddle performs a distinct function in the harness frame and in weaving that should never be overlooked Heddles serve the purpose of holding the yarn in the desired position either in the upper or lower shed and keeping it there until the shuttle has passed through this shed and introduced the filling yarn Heddles must also move the yarn from the lower to the upper shed or vice versa in accordance with the weave that is used In addition, it must be so constructed that it allows a forward movement of the warp yarn during weaving, irrespective of knots Heddles that have rusty, rough, or sharp eyes will not perform properly A great deal of damage can be done by such heddles Quite often heddles become cut or damaged in use They should be inspected periodically and the damaged heddles broken out and replaced at once

Freedom of the heddles in their sideward movements is essential Flat heddles slide easier than twin wire heddles Sticking heddles are the cause of much warp breakage and reduced loom efficiency

Heddles are generally brushed well after use, oiled, and then wiped off If they become badly rusted, they should be cleaned with cocoanut oil or compounds sold for this particular purpose When placing the desired number of heddles on the harnesses required by the weave, care must be taken that they are not too crowded on each harness Bent, crooked, or damaged heddles should be broken out. Tied-in, spare, or repair heddles are those that are inserted temporarily by the weaver when a heddle breaks during weaving. They should be broken out and replaced by a new heddle in the particular harness

Drawing In Drafts

A drawing-in draft is prepared by the fabric designer and is used by the drawing-in girls to draw the warp through the heddle eyes Drawing-in drafts are usually worked out on squared design paper and should be kept simple The drafts are prepared so that a minimum of errors or misunderstandings occur in the drawing-in department The weaver also gets a copy of the draft, if it is out of the ordinary or not easily understood.

The drawing-in draft, or the manner of drawing the individual yarns through the number of harnesses, shafts, or leafs required by the weave, is worked out to permit the use of the smallest number of harnesses The operation of the harnesses, the particular threads drawn through each heddle on each harness, are important factors which affect and control the production of the correct weave and cloth A drawing-in draft is necessary on all types of cloths except simple weaves

In the design or weave pattern, the drawing-in draft concerns itself with those warp threads that act alike (i e, are up or down together with respect to the filling) and it is these threads that must be drawn on the same harnesses, instead of employing separate harnesses for each individual thread in the pattern Hence, in this manner very elaborate stripes and weave patterns may be drafted down to a comparatively few harnesses, saving much labor and extra equipment. In addition, it must be considered that each loom is limited in the number of harnesses it can accommodate In woolen and worsted looms the largest number of harnesses that can be operated economically is generally 24 to 26 That means all fabric designs and patterns, no matter how complicated are reduced and adjusted to take no more and, if possible, considerably less than 24 harnesses

Types of drawing-in drafts The drawing-in draft must be clear simple, and easily understood, otherwise it fails its object It can become a very complicated piece of work, particularly when

color patterns or effect weaves are used Drawing-in drafts may be classified into the following types.

1 Straight draw
2. Broken draw.
3. Pointed draw
4 Scattered or satin draw.
5 Intermittent or skip draw.
6 Grouped draw.
7. Divided draw.
8 Manifold draw.
9 Combination draw.

1. The most common and preferred drawing-in draft is the *straight draw,* by which is meant that the yarns from beginning to end of the warp are drawn straight through the harnesses It must be pointed out that for this purpose the harness frames are arranged parallel to each other, one in back of the other. The harness designated harness 1 is always nearest the reed in the loom and the weaver, whereas harness 12 would be farthest away, all of them arranged one directly behind the other in direct sequence, such as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12.

For the straight draw the first thread in the warp is drawn through the first heddle of the first harness, the second end is drawn through the first heddle of the second harness The third end is drawn through the first heddle of the third harness and so on until the twelfth end is drawn through the first heddle of the twelfth harness From there on the whole order is repeated In other words, the thirteenth end in the warp is drawn through the second heddle of the first harness and the fourteenth end through the second heddle of the second harness and so on across the entire warp This method should be and is used wherever the pattern or the weave permits it For both the drawing-in girls as well as the weavers it is the best draw because it is simple and can be followed with a minimum chance of error.

However, in a good many cases fancy drafts, of which there are many, are required and for such goods special drawing-in drafts have to be prepared and copies made for the drawing-in girls as well as the weaver or weavers who will run this particular style For this purpose different mills use different methods

Probably the simplest method is to let horizontal lines represent the harnesses involved (1—24) and vertical lines the warp threads The point at which the vertical line stops indicates the heddle through which the particular warp thread is to be drawn It indicates at a

glance the order of drawing-in that should be used (See Fig 15) Some designers indicate the numbers of the harness at the junctures and others designate the juncture with crosses, in order to facilitate the working out of the design Still others use design paper and indicate the harnesses by numbers All of these methods are practical and are largely matters of personal preference Sometimes the drawing-in draft is referred to as the *treading plan,* which is a term handed down from hand-loom days

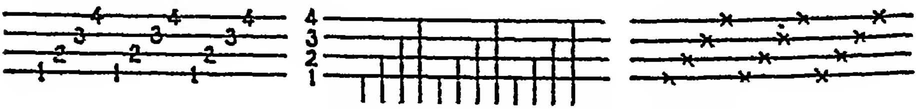


Fig 14 Methods of designating drawing in drafts

In brief, the straight draw proceeds in one direction only The number of threads in a straight draw is equal to the number of shafts or harnesses and each shaft carries one end for every repeat of the draw.

2 The *broken draw* is characterized by one group of threads which is drawn in straight in one direction and another group which is drawn in straight in the opposite direction Where the direction is reversed the first end of a new series is started higher or lower than the last end of the preceding series Twills woven with this draft run forward and backward in the order of the draw, as in herringbones The broken draw is generally preferable to the pointed draw and is used more frequently A better junction of the twill lines is attained than with a pointed draw.

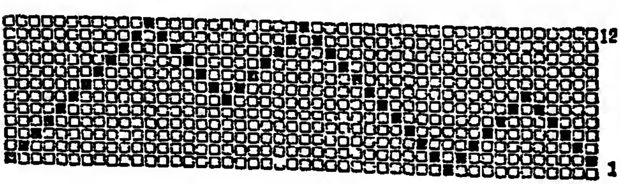


Fig 15 Typical example of a pointed draw

3 The *pointed draw* runs straight first in one direction, and then in another The shaft at each point of reversal receives but one end, whereas the other shafts carry two ends It is not necessary, of course, that each line covers the same number of ends or shafts The direction can be changed also at irregular intervals With a definite twill weave, by varying the order of reversing a pointed draft, many attractive effects can be created Only one objection in some classes of goods is found, namely, that at the point of reversal the filling floats over

several extra threads, causing too large floats that are easily distorted or broken.

4. In the *scattered* or *satin draw,* the order of drawing the warp is scattered irregularly, resembling the draft of a typical satin weave It is not used except when necessary because of the difficulty in following it in the drawing-in department

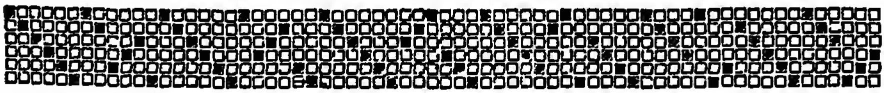


Fig 16 Intermittent or skip draw

5 The *intermittent* or *skip draw* is generally a straight draw except that at short intervals a certain number of shafts are skipped, the number depending on the weave that is used The first and the last threads in these draws should break with each other

6 The *grouped draw* is used in stripes, checks, and fancy effects where two different weaves are employed One weave operates on one set of shafts, and the other on another set or group of shafts

7 The *divided draw* is commonly employed in warp-backed and double cloths The face and back threads are drawn on separate groups of harnesses and hence the drawing-in draft is divided The shafts working the face threads are usually hung next to the reed, or in front, whereas those of the back weave are handled by the rear harnesses There is an exception made to the above, when the back warp is weaker than the face A typical example is shown in Fig 17

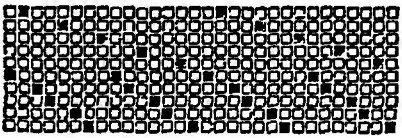


Fig 17 Divided draw

8 The *manifold draw,* also termed the *corkscrew draw,* is used where each twill line is formed by alternate ends It is effective where twills are formed with different colored yarns In even numbered shafts they are divided into equal groups, odd numbered shafts and even numbered shafts For example Nine shafts are divided into two parts, 1 to 5 and 6 to 9, the first twill begins on shaft 1, the second twill on shaft 6 Corkscrew weaves commonly are drawn into the harnesses in this manner

9 *Combination drawing-in drafts* come about through a combination of the draws 1 through 8 and when figure or dot weaves and ground weaves are employed, as in fancy worsteds Every possible weave pattern can be made with these eight draws, but it should be remembered that complicated combinations are difficult to follow

Drawing-in drafts, therefore, have an important influence in weaving They should contribute to the formation of a clear shed; they should be as simple as possible and arranged so that the warp ends will be distributed uniformly over all the shafts They should aid in relieving unnecessary strain on the warp yarn Generally, the threads with the least amount of interlacing are drawn on the back harnesses The draw should aid in keeping the number of harnesses to a minimum, because drawing-in and weaving costs rise with the number of shafts used Practical experience and a thorough knowledge of weaves determine what drawing-in draft is best under any given circumstance

To illustrate what is meant by "drafting weaves" and to determine which is the best drawing-in draft to use, the following will serve as an example The weave consists of 16 ends of a 2/2 45 degree twill, running left to right, followed by 16 ends of a 2/2 45 degree twill, running right to left, joined by an offsetting of the twill as in typical men's wear fabrics Three different drawing-in drafts are possible, see, in Fig 18, the weave with the corresponding chains beneath The draft to use depends on the number of harnesses practical in weaving The first one (I) shows a necessary minimum of four harnesses but such weaves are more generally proven on eight harnesses, because of better loom operation Hence, the second draw (II) is probably the best The third draft (III) is a scattered or satin draw, perfectly satisfactory except that it is not easy to draw without making an error at the junctures of the weaves or sometimes during the drawing-in of the whole warp Hence, III should be avoided

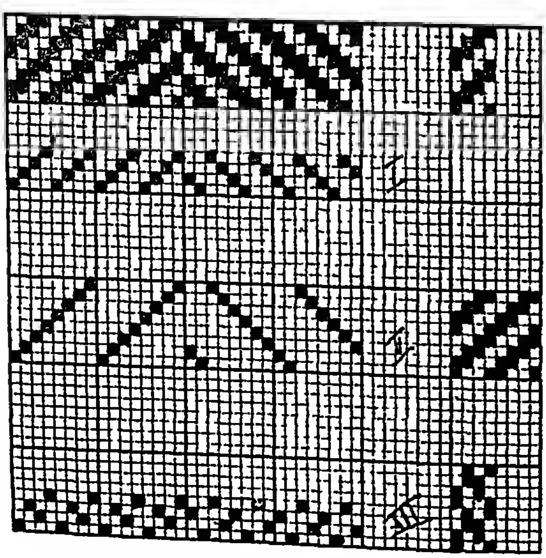


Fig 18 Different methods of drafting a weave

In the chain each end that operates differently is recorded The chain serves to actuate all the harnesses on any given pick It raises those harnesses, the ends of which shall be in the upper part

of the shed and up or over the filling A peck or roller on the loom is used for that purpose in place of the filled-in square shown in the design paper. The chain is made on the basis of the drawing-in draft and the original weave Only those ends which act differently from all others in the weave are utilized in making the chain The length of the chain is controlled by a repeat of the weave in the direction of the filling If it should be less than four picks, double the length is made because the loom demands at least four bars to a chain

Reeding of the Warp

Reeding follows drawing in of the warp yarns and is done in the same department directly after drawing in Reeding consists of drawing the warp yarn through a series of splits in a comblike device that serves the following purpose in the loom

1 To distribute and hold the yarns evenly at a definite width known as reed width in the loom.

2 To act as a back rest to the shuttle, which passes in front and across its length.

3 To beat the filling yarn into the woven cloth during weaving

There are two types of reeds used in woolen and worsted work, namely, the pitch-band reed and the metallic reed Both of these are shown in Fig 19 The first is a reed (or a comb closed on both sides) which is made of thin flat strips of steel set in two pieces of wood, called "ribs" Each rib consists of two parts and is wound with pitched cotton cord of specific size in order to space the rib exactly as desired and to make the whole reed firm and strong The space between any two adjacent steel strips is known as a split or a dent The number of the dents or spaces per inch of width designates the number of the reed If a reed has 12 spaces, splits, or dents per inch, it is designated as a number 12 reed, if it has 16 spaces per inch, it is

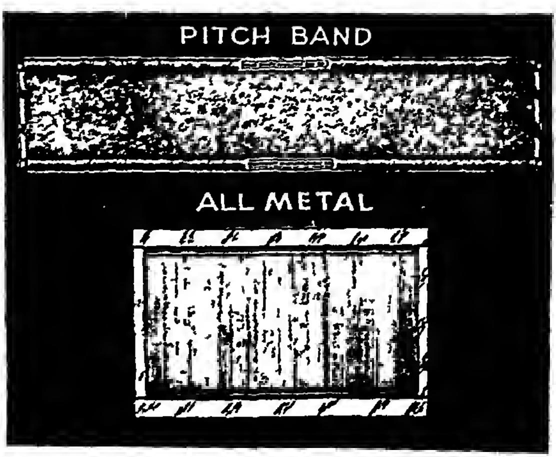


Fig 19 Types of reeds

known as a number 16 reed Some manufacturers indicate their reeds by the total dents on a given width, for instance, 620—62 reed, which means 620 total dents in 62 inches of width, being equal to a number 10 reed

The depth or height of the reed is usually 5¼ inches, but may vary from 4 to 6 inches according to the kind of goods being woven as well as the size of shuttle employed In carpets and felts the height may be 8 or 9 inches

Metallic soldered reeds are also employed for fine worsteds They are more expensive but have distinct advantages They can be had up to 60 dents per inch for fine worsted goods

The passing of the harnessed warp yarns through a reed is accomplished in accordance with the drawing-in draft, on which the denting or reeding is indicated by the designer This is done when the reeding plan is irregular or out of the ordinary When reeding is regular and uniform, the designer indicates on the order ticket what size reed shall be used and also how many ends per dent shall be taken This may be different for the selvage than it is for the body of the warp If it should state 10 reed 4 per dent, it means that a number 10 reed, which has 10 dents per inch, shall be used In each dent of that reed for the width specified shall be placed 4 adjoining warp yarns at a time

To make this still clearer, a typical women's serge is taken as an example The specifications state that this particular cloth is to be 63 inches in reed, has 3,456 ends and 72 selvage ends, a number 14 reed is to be drawn with 4 ends per dent This means that a reed must be selected from stock that is at least 63 inches wide, has 14 dents per inch or a total of not less than 63 x 14 or 882 total dents, into each one of which are placed 4 ends, making a total of 882 x 4, or 3,528 ends including selvage The width of the reed is usually selected a little wider than 63 inches, to fill the spaces between the shuttle box and reed on each side of the lay or batten

Girls perform the reeding operation by means of a reed hook or reed knife Two girls are necessary, although one experienced girl can do it alone The operator usually works from right to left, if a right-handed girl, and vice versa, if a left-handed girl The warp with its harnesses is placed in a wooden stand The short ends of warp yarns are drawn through a little farther to permit them to reach through the reed, which is now placed in front of and level with them The operator passes the reed knife through the first dent (not necessarily the first dent in the reed on the right) and takes successive warp ends in a group of four, hooks them with the reed knife, and draws them through the dent so that they now appear on the other

side of the reed. The hook is now inserted in the next dent and the next four successive ends are picked up and hooked through This is repeated across the entire warp until completed No ends or dents shall be skipped, unless so intended.

Reeding is done very rapidly by an experienced operator or even faster if two girls work at it. One is known as the "hander-in" and the other "the reeder." No dents may be skipped and errors must be corrected at once When the reeding is irregular the task becomes quite difficult After a group of twenty or more ends have been reeded, they are knotted with half-knots or loops to prevent them from being pulled out by accident.

The coarser reeds are generally employed in woolen and worsted work and reeds of No 30 or finer are rarely employed The coarser the reed the less friction and strain there will be on the warp yarns The finer the reed the smoother the texture of the woven fabric. The number of ends per dent may vary from two to eight and changes with each type of cloth. If difficulties are encountered in weaving, i e, poor shedding of the yarn or excessive end breakage, it may become necessary to re-reed the entire warp This should not happen, however, to an experienced designer How many ends per dent should be used is something which requires practical experience and good judgment.

The care, storage, and preparation of reeds is an important factor in good weaving of the warps Much damage can be done by bent or otherwise damaged reeds, rusty reeds, or unsuitable reeds They can be the cause of the so-called "reed marks," which are usually streaks or stripes in the direction of the warp produced by imperfect spacing of the warp yarns Also, when certain dents or all dents have too many ends per dent, they can cause rolling or over-riding of the warp yarns, an undesirable appearance in some weaves

Reeding is still a hand operation and probably will continue to be A mechanical reeding machine has been invented in Europe and is now built in the United States, although it has not been extensively adopted in this country.

The warp is now completely prepared for the loom with its harnesses, heddles, beam, and reed securely rolled up and fastened It is allowed to rest on the floor until demanded by the weave room, when it is carefully placed on a "horse" or oval truck and taken to the particular loom, the old warp of which has been finished

Mechanical Twisting In or Drawing In

On staple lines or fabrics that are made constantly year in and

year out, the drawing in can be done by a machine designed to do this work automatically and often much faster than it can be done by hand Most mills working on the same or similar goods employ hand and machine twisting-in. Twisting-in a warp means connecting the ends of a new warp to the ends remaining from a former warp which has been woven out in a loom, or cut out for various reasons This can be done at the loom or in a special space set aside for this purpose Of course, to be successful and applicable, the new warp yarn must be exactly the same type and twist as the old The warp should have approximately the same number of ends Only on these conditions can the ends of each warp, end for end, be twisted together until the whole warp is completed The twisted ends are then drawn carefully through the heddle eyes in the harnesses and the reed as well The warp is then ready to be woven again, without repeating the laborious drawing-in of the heddles and reed by hand

The question of whether or not it is cheaper to draw in warps by hand or machine can only be decided by the class of goods woven and by the type of help and facilities of each mill Manual help has been replaced by the tying-in machine, invented to do this work The machine is almost human and selects an end of the old warp and knots it to the corresponding end in the new warp until the whole warp is finished The ends of the knots are trimmed and the machine is provided with a stop motion and other devices It stops when a knot is not complete or slips, as well as when an error is made. Of course, the warp must have a correct lease in it, as well as the new warp, so that no crossing of ends occurs Whiting and oil are used by the hand twister-in to ensure sticking of the twisted ends If yarns of different size or count and twist are in the new warp, it may become necessary to use knots instead of twisting them together by hand

Hand twisting-in has been pretty well discontinued by most mills and a mechanical twisting-in or tying-in machine is used They are manufactured by two companies in the United States, and will do drawing through drop wires, special flat heddles, and reeds

Rewinding for Filling Purposes

A new automatic filling bobbin winder is on the market and used extensively by woolen and worsted mills because it was found impractical in many cases to use the bobbin produced on a ring spinning frame When larger shuttles were introduced, it was necessary to use a filling bobbin that would fit into the shuttle but, at the same time, be as large as the shuttle in use would permit This necessitated a

rewinding of the filling bobbin as it came from the spinning or twisting rooms Such a winder is shown in Fig 20 The machine affords an opportunity not only to rewind the filling yarn to ensure greater efficiency in weaving on automatic looms, but also to inspect the filling yarn and to take advantage of large package woolen spinning In the case of bought yarn, the supply package may be cones, tubes or dye house packages and twisted bobbins and rewinding would be necessary in any case.

By means of this automatic filling bobbin winder, the yarn supply package is placed in a magazine-type creel so that the tail end of one package may be tied to the leading end of the next package, permit-

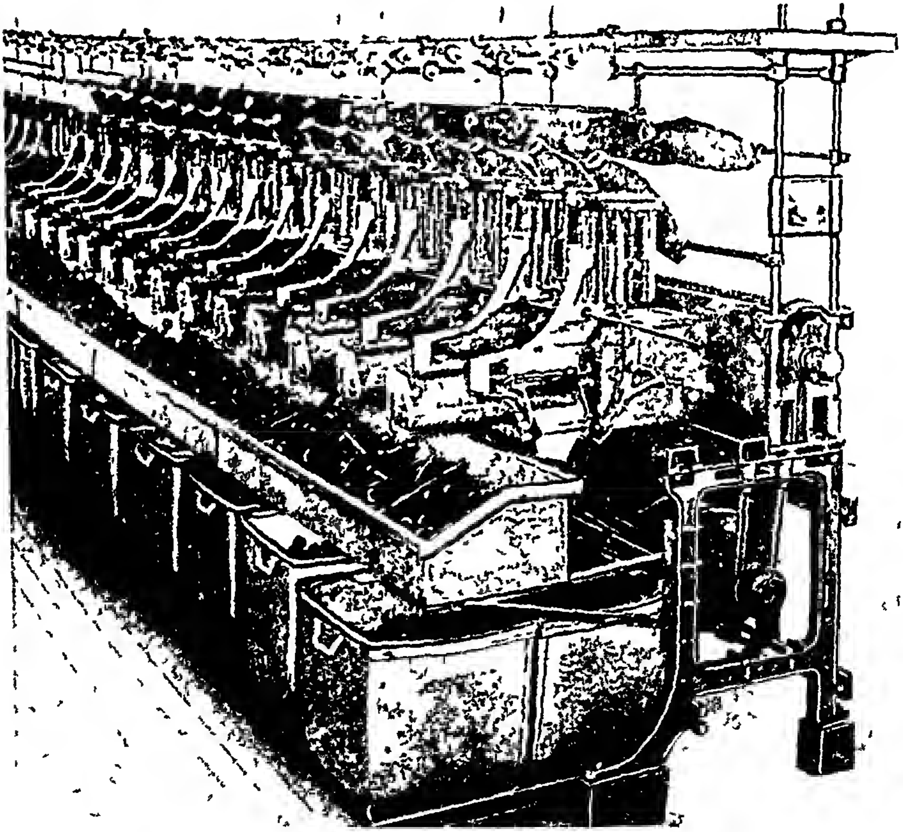


Fig 20 Whitin-Schweiter automatic filling bobbin winder
Courtesy Whitin Machine Works

ting *continuous* operation during creeling The yarn is taken off over end and passes through a suitable tension device, according to the type of yarn run It passes next through a porcelain guide, which acts as a stop motion element in the event of yarn breakage, run-out of the supply package, or lack of sufficient tension From this point, the yarn travels through a porcelain-lined oscillating thread guide which lays it on the rotating bobbin and moves forward according to the predetermined diameter of the bobbin

Fully wound bobbins are ejected automatically and empty bobbins reinserted in their proper position All bobbins can be built to the same thickness, density and yardage of filling yarn The winding spindle operates at 3,500 to 5,000 r p m and the production of woolen yarns on this winder ranges from 74 lbs per spindle per 40 hours on eight run yarn to 400 lbs per spindle per 40 hours, with a bobbin diameter of 5/8", full diameter of 1-5/16" and a traverse of 8¾" On worsted yarns, lower production is attained It ranges from 31 lbs per spindle per 40 hours on 50s yarn to 100 lbs per spindle per 40 hours on 12s yarn with an empty bobbin of 9/16" diameter, full diameter of 1-3/16" and a traverse of 7⅞" and a spindle speed of 5,000 r p m and 4,000 r p m , respectively

The winder operates quietly, is built in units of 6 to 42 spindles, can be adjusted to any bobbin size, the taper and traverse can be adjusted to suit particular yarns or weaving conditons It requires anywhere from ¾ to 4½ horsepower and occupies a very small space It has many excellent features and is fully automatic and requires little supervision.

Chapter 16

THE WEAVING OF WOOLENS AND WORSTEDS

The Principle of Weaving

WEAVING constitutes the actual production of cloth or fabric as distinguished from knitting, braiding, and lace making, which are the other methods of producing fabrics Two fundamental facts that can be noted from examination of any woven goods are that it has length and width The width of a finished fabric may be from 18 to 35 inches; such fabrics are called narrow goods The width may be from 36 to 58 inches, and these

Fig 1 Worsted dress goods weaving (*Courtesy Forstmann Woolen Company*)

fabrics are known as broad or wide goods. Felts, carpets, draperies, velvets, etc, can be woven as wide as 500 inches In fact, the widest loom ever built in the United States was a loom 540 inches between swords for the manufacture of papermaker's felt These fabrics are of extra and unusual width, however

The length of a piece or "cut" is usually 50 to 70 yards long, and in a few cases, 120 to 140 yards, known as double cuts

When a woven cloth is examined further, one can observe that there are a series or number of yarns or threads running lengthwise, spaced equally or unequally, but generally running parallel to each other Another set of yarns or threads run crosswise (from selvage to selvage) which are spaced equally and uniformly apart These two sets of yarns normally intersect or interlace at right angles to each other and form a solid, well-bound, and often thick fabric. Fabrics differ in character, surface, and texture. They may be thin or thick, single or double, rough or smooth, open or closely set, and so forth

But, whatever the fabric, the following simplified definition of weaving applies

Weaving is the forming of a textile by the interlacing, at right angles to each other, of two sets of yarns, one running lengthwise in the loom and termed the "warp" and the other running crosswise in the loom and termed the "filling" or "weft"

Woven woolen and worsted fabrics are produced on what is termed a "loom" The development of weaving is one of the most interesting studies one can pursue From the crude methods of hand weaving practiced by the Pilgrims, the Puritans, and others in colonial days, the mechanical loom was gradually developed in this country through the genius of such inventors as William Crompton, Lucius Knowles, Erastus B. Bigelow, and others It was not until 1837 that weaving was done by mechanical looms and this development is described in Chapter 1

The present woolen and worsted loom is indeed the most advanced piece of machinery in the whole industry and the result of much experimentation, engineering skill, and precision These looms are built in this country by the Crompton & Knowles Loom Works, whose research engineers and mechanics have produced a loom that meets every possible requirement of American woolen and worsted manufacturers The plant at Worcester, Mass, covers over 20 acres of buildings and grounds and employs from 1500 to 2000 people

The Eight Essential Motions of a Loom

In all looms there are eight principal mechanical motions or operations involved in the weaving of woolen and worsted fabrics They are:

1 Shedding, harness, or head motion (separation of the warp)
2 Picking motion (insertion of the filling)
3 Beating-up or lay motion (placing picks into the cloth)
4 Letting-off motion (warp supply)
5 Taking-up motion (taking away of the woven cloth)
6 Filling bobbin replenishment motion
7 Automatic stop motions (center-filling, warp, and protection stop motions)
8 Box motion, in multiple box looms, where more than one color filling is employed (Described as part of motion 1 in the text following)

These motions play a principal part in the operation of a loom as well as in the production of merchantable cloth They take place simultaneously and each will be described in this chapter in detail, in order that a full appreciation of their function, operation, and effect in weaving may be obtained

Before proceeding with the explanation of these mechanical motions, it becomes necessary to explain the simple principles of mechanical weaving in general This will be done on the basis of a simple side elevation of a loom and its essential parts

Figure 2 shows the essential parts of a loom designated with letters for each part With these designations as a guide it will be less difficult to understand the sequence of operations necessary to produce a woolen or worsted fabric on a loom, irrespective of its type The sheet of the required number of warp yarns is properly prepared and placed on warp beam A, from which the warp yarns are passed in a vertical sheet up and over whip roll B, which brings the warp yarns into the horizontal level with the harnesses Before they pass into them, they are threaded through two lease rods C, which serve the purpose of separating the warp yarns into two groups, one passing *over* the first lease rod and *under* the second, and another group, which pass *under* the first lease rod and *over* the second Usually, the lease rods are alternated so that the yarns are in perfect order and can be kept that way when warp breakage occurs during weaving From there the yarns pass through the harnesses, of which only two are shown in the diagram There may be as many as

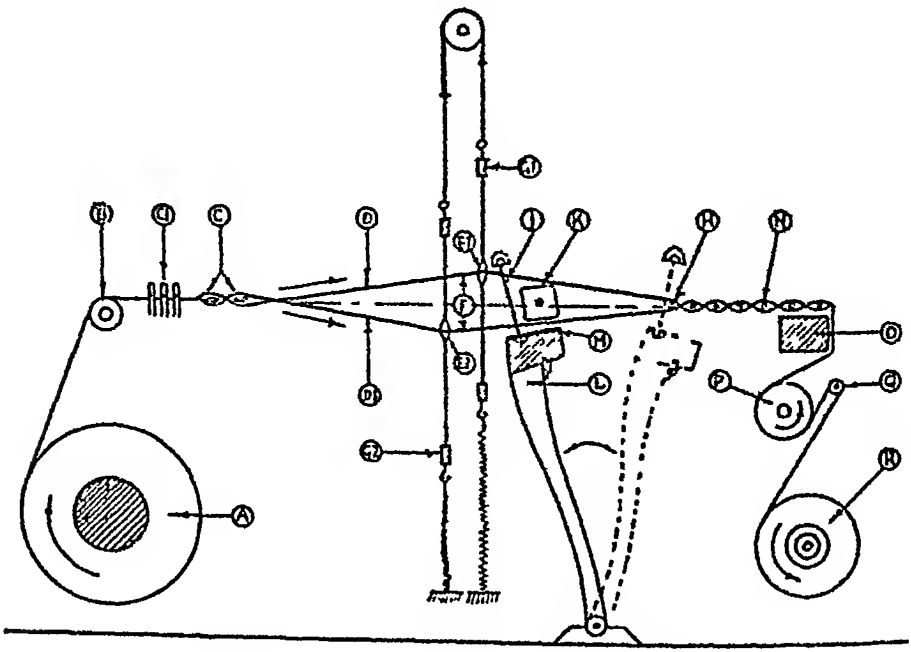


Fig 2 Essential working parts of a loom.

A —warp and warp beam
B —whip roll
C —two lease rods
C1—warp stop motion
D —One or group of warp yarns in upper shed
D1—One or group of warp yarns in lower shed
E1—heddle eye in first harness
E2—heddle eye in second harness
G1—harness one
G2—harness two
L —lay or batten
I —reed and reed cap
M—race plate
K—shuttle in shed
H—fell of cloth (beginning of woven cloth)
N—already woven cloth
O—breast beam
P—sand roll or take-up roll
Q—guide roll
R—cloth roll

twenty-six in modern worsted looms The yarns are drawn through heddle eyes E1 and E2 of the heddles placed on harnesses G1 and G2 One end is generally drawn through one harness, the next through the other, and so on alternating constantly The function of the harnesses is to separate the yarn sheet into two groups, one upper and one lower, forming an opening known as shed F At first, harness G1 is up and harness G2 is down and on the next movement or pick, harness G1 is down and harness G2 is up and

so on alternating consecutively with each pick inserted This is technically known as the "shedding" operation

In front of the harnesses is located a lay or batten L, which carries reed I and has a race or race plate M Lay L oscillates forward and backward as shown by the two positions in the diagram The warp yarns pass through the dents of reed I, which spreads the yarn evenly across the desired width and acts as a backrest to shuttle K, which carries the filling yarn on a bobbin Shuttle K passes through open shed F when the lay is in its backward position in front of reed I on race plate M and from one side of the loom to the other. For a top view and front view of a modern worsted shuttle, see Fig 3.

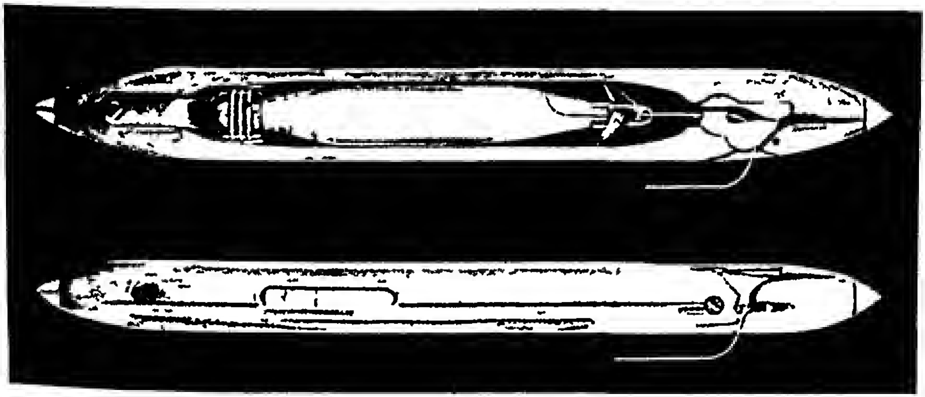


Fig 3 Top and side view of automatic worsted shuttle

When the shuttle has passed through the yarn shed and has introduced one filling thread, or, as it is technically called, a "pick" or "shot," the lay moves forward and the shed closes, pushing the inserted filling yarn by means of the reed up to the fell of cloth H, where the last pick is now located The propulsion of the shuttle is known as the "picking" motion and the forward movement of the lay with its stationary reed is known as the "beating-up" motion

The operations of shedding, picking, and beating-up take place successively and they constitute the three principal motions in weaving any cloth When the last pick is beaten up, the lay moves backward again and while the harnesses change, the warp yarns again separate into two groups forming a new shed When the lay has half completed its backward movement, the shuttle is "picked"

across and another pick inserted The lay again moves forward to beat the filling up and the harnesses close This operation repeats itself rapidly at the rate of 125 to 180 times a minute, according to the speed of the loom

The cloth begins to take shape at the fell of cloth H and slowly moves on over breast beam or breast roll O down over a sand roll or take-up roll P, circling its circumference almost completely and over a guide roll Q down to cloth roll R, which winds it up at full width Sand roll P is covered with perforated tin or fine sandpaper and moves the woven cloth very slowly in direct accord with the number of picks that are to be inserted per inch of woven cloth In fact, the sand roller is driven by change gears, which control the desired picks per inch in the cloth Sandpaper is used in order to get a firm grip on the cloth When a piece or cut of cloth has been woven (to a length of say 60 yards), it is cut across and taken off the cloth-roll shell, which is then replaced in the loom Direction of rotation of yarns and loom parts are indicated in Fig 2 by arrows This procedure goes on as long as a supply of warp yarn and filling yarn is available

When the bobbin of filling yarn in the shuttle ran empty, the loom used to be stopped, the shuttle removed from its receptacle or box on either side of the loom, the empty bobbin or cop removed and replaced by a full one threaded through the shuttle eye, the shuttle returned to its receptacle or box, and the loom started up again Today, this whole operation is done automatically without stopping the loom The let-off pertains to the constant supply of warp yarn as needed The take-up concerns the motions necessary to move the cloth and warp at such a rate as is required by the number of picks in the cloth

Understanding of this procedure is essential, because the modern automatic woolen and worsted loom, while it still performs these simple motions in exactly the same way, has many additional motions and safeguards which serve to make the loom more efficient, permit higher speeds, eliminate vibration, and tend to make it nearly automatic The eight principal motions as listed will now be described in mechanical detail as they are found in modern, high-speed woolen and worsted looms Knowledge of these operations is required of the loom fixer and loom mechanic, whose duty it is to set up these looms and keep them in good working condition One such loom fixer usually cares for eighteen to twenty-four of these looms, depending on their age The older the looms are the less looms he can take care of and the more fixing he has to do

Lubrication of the loom Woolen and worsted looms are sometimes equipped with "one shot" lubrication, which lubricates thirty-five of the important bearings on the loom A tank of oil with a pressure lever supplies one cubic inch of oil to all important bearings

Head or Harness Motion

The head on a loom is the part which performs, actuates, and controls the motion of the harnesses in a loom. In cotton and silk looms this part is often designated as the dobby. The Crompton & Knowles head motion is more sturdily built than a dobby and is a positive motion in every respect It is of special value on wide fabrics and fancy weaves. Ordinarily the control of the boxes or shuttle receptacles, especially on looms having more than one box on each side of the loom, is combined with the harness motion in the head, so that it becomes impossible for them to get out of time

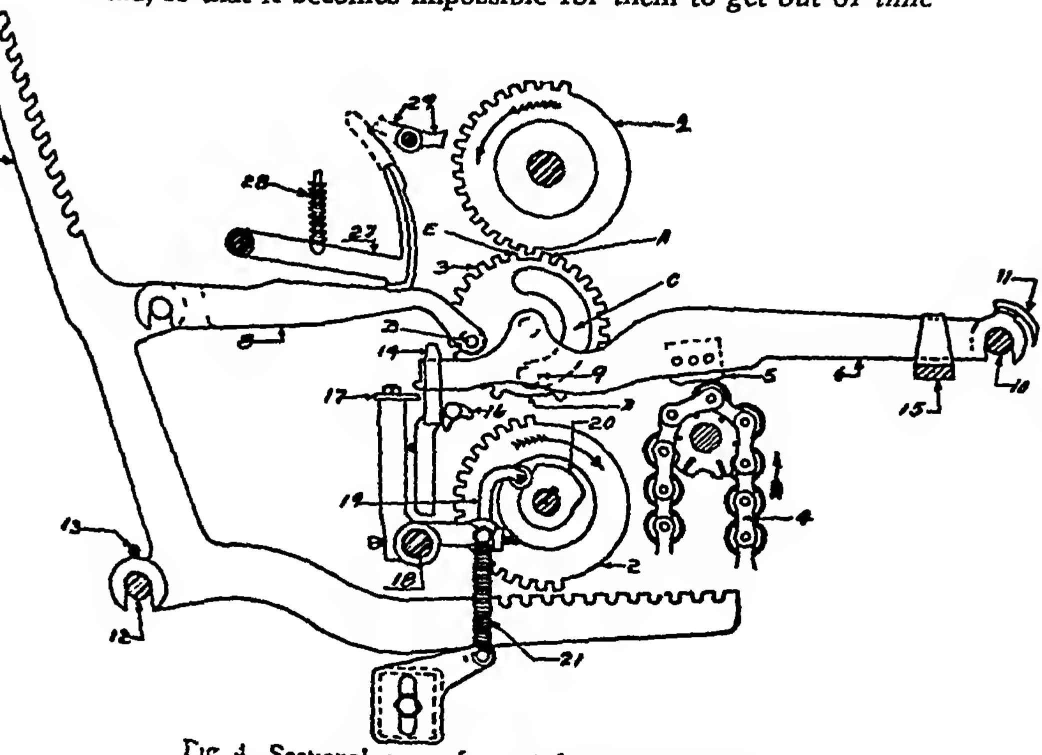


Fig 4 Sectional view of worsted-system head motion (Courtesy Crompton & Knowles Loom Works)

A sectional view of the head is shown in Fig. 4 Top cylinder gear 1 and bottom cylinder gear 2 rotate in opposite directions as shown by arrows Between these cylinders is partial gear 3 (there is one for each harness) which has a blank space equivalent to about three teeth at one point and another blank space about equal to one tooth directly opposite The combination of lever 6, gear 3, and connector 8 is known as a vibrator, there being one for each harness Harness chain 4, consisting of metallic rolls and tubes, raises or lowers this gear by contact with run 5 on vibrator lever 6 on which gear 3 is pivoted Run 5 is held to the vibrator by two rivets and may be readily replaced when worn.

As shown in Fig 4, gear 3 has been raised and the first tooth of cylinder gear 1 is just coming into contact with tooth A of vibrator gear 3 The vibrator gear will be turned a little over half a revolution, pulling forward harness jack 7 by means of connector 8 between the gear and the jack Point B is therefore brought to point C and is locked there, as point C is below the line from the center of vibrator gear 3 to the boss, where connector 8 hooks onto jack 7 Just as this locked condition is reached, the wide blank space D on the vibrator gear disconnects it from the cylinder gear and no change in position of the harness will take place until a tube on the pattern chain allows the vibrator to drop down into position for contact of the gear with lower cylinder 2, at which time just the reverse motion takes place and the harness is lowered, the lower cylinder strikes tooth E and rotates the gear back to the position shown in the diagram

Connections from the top of a harness frame are fastened to the vertical arm of jack 7 and from the bottom of the same frame connections are made to the horizontal arm of jack 7 The result is a positive motion.

Vibrator gear 3 is cut out in part as shown, and in combination with a round boss 9 on the lever 6, within the slot, a definite stop for both upper and lower harness positions is provided Therefore connector 8 at position B or C never rests on vibrator lever 6 The vibrator levers are set onto a heel pin 10 capped by a heel shell 11, which may be easily removed to take out the vibrators Connector 8 is fastened to jack 7 by means of a split hook which slips over a boss on each side of the harness jack The harness jack is pivoted on jack pin 12 There is a guard rod, or so-called overjack pin, as shown at 13

The vibrators are spaced by combs 14 and 15 Evener 16 serves to determine the low position of the vibrators and to raise the

vibrators by hand for levelling the harnesses Run 5 on the vibrator lever should clear a tube on the chain when the lever is in its low position The upper position of the vibrator is controlled by the chain roll The harness chain is of the familiar roll and tube type Either hardened cast iron or hardened turned steel rolls are used

A section of the chain shaft is indicated in Fig 4 It is divided into "buckets" into which the rolls fit The rolls bottom on the shaft and are supported on each side by the adjacent bucket walls The chain rolls are not supposed to turn when moving under the vibrator runs The chain shaft is set so that the chain roll contacts with one end of the vibrator run just as a roll on the next bar ahead is leaving the run The buckets on the chain shaft will position the rolls so that slight wear of the chain links will not affect the motion of the vibrators Chain 4 should be kept well oiled

An important element is lock knife 17, which is carried on an arm on shaft 18 It is governed by finger 19, which is held against cam 20 by coil spring 21. The lock knife is "in" or close to comb 14 during harness change, and "out" while the vibrators are changing. The duty of the lock knife is to hold the low vibrators from being lifted by the lower cylinder gear, while the latter turns the vibrator gears The ends of the vibrator levers, which are up, should clear the lock knife blade. It is not intended to wedge the levers apart or to hold them apart The adjustment at this point is very important The head is driven from either the bottom shaft or the crank shaft by means of gears which drive an upright shaft.

Box motion The box motion is a unit with the Knowles head The shuttle boxes are controlled by vibrators in the same manner as the harnesses, and the short cylinder gears for operating the box vibrators are screwed to a flange on the shaft along with the harness cylinder. One lock knife may extend across both harness and box vibrators, but on some heads the box section has a lock knife separate from the harness section and controlled by another cam

The vibrators are controlled by box chain 31, shown in Fig. 5 Box vibrators 32 and 33 work as already explained and in so doing move levers 34 and 35 Lever 34 is pivoted at the lower end and holds box lifter chain 36 at a point on the lever about midway between the pivot and the vibrator connection The movement given this lever by its vibrator 32 represents a one box lift Lever 35 is pivoted at the center, and at its lower end is sheave 37 around which the chain passes from lever 34 to the drop box. The motion given lever 35 by its vibrator 33 represents a two-box

lift Together they lift three boxes, or in other words, control a four-cell box If the loom is 4 x 4,* this mechanism is doubled and two additional vibrators control the boxes at the other end of the lay.

Box lifter chain 36 passes around sheaves to an adjustable rod fastened to casting 38 on the box lifter rod This casting is a sleeve which has a sliding fit on the box lifter rod and in rocker 39 Spring 40 around the box lifter rod holds sleeve 38 down against collar 41, set-screwed to the bottom of the box rod Therefore, if the shuttle

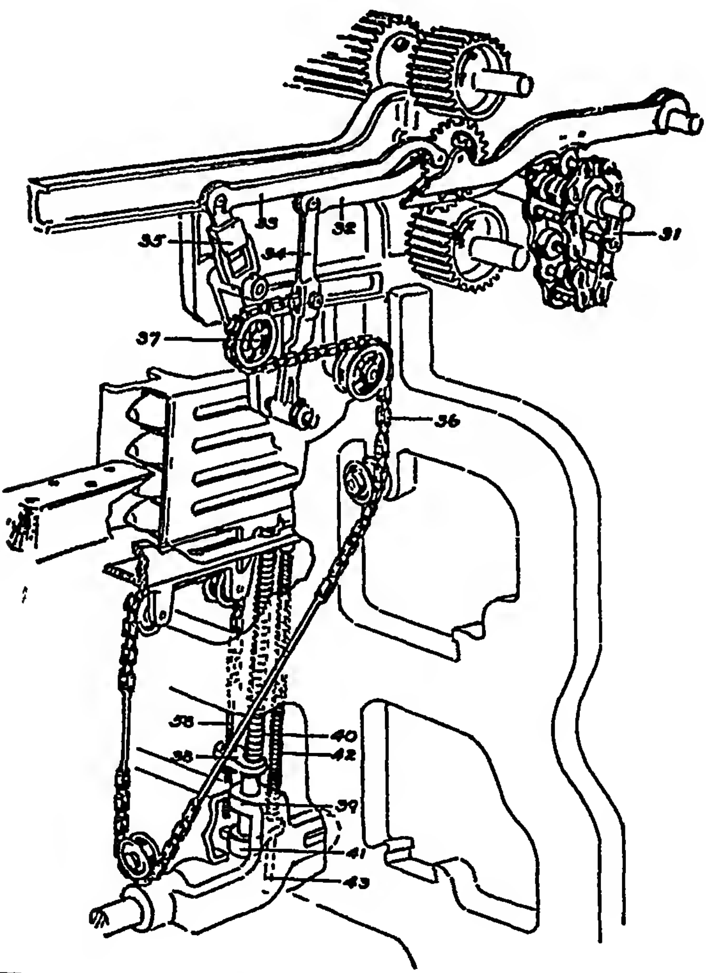


Fig 5
Box motion connections on head motion of a loom
(Courtesy Crompton & Knowles Loom Works)

* Four boxes on each side of the loom

is not fully in the box, as the latter rises the sleeve 38 will slide upward on the box rod and compress spring 40, preventing damage

Spring 42 is used to push the box down, as it is best not to rely upon gravity alone This spring is guided by rod 43, the upper end of which is held in a socket in the lay end by pressure of spring 42 against a collar near the top of the rod, and at the lower end it passes through a hole in collar 41 at the bottom of the lifter rod The spring pushes down on collar 41 which, as stated above, is fastened to the box lifter rod In this manner any box can be brought into play by building a box chain to suit the particular requirements

Picking Motion

The picking motion concerns the propulsion of the shuttle from one side of the loom to the other at the rate of from 100 to 180 picks or passes per minute It is one of the most important motions on a woolen and worsted loom and consumes three quarters of the power required to run the loom It is the motion which makes the greatest noise on the loom and commands the most time from the loom fixer The picking motion is explained by means of Fig 6,

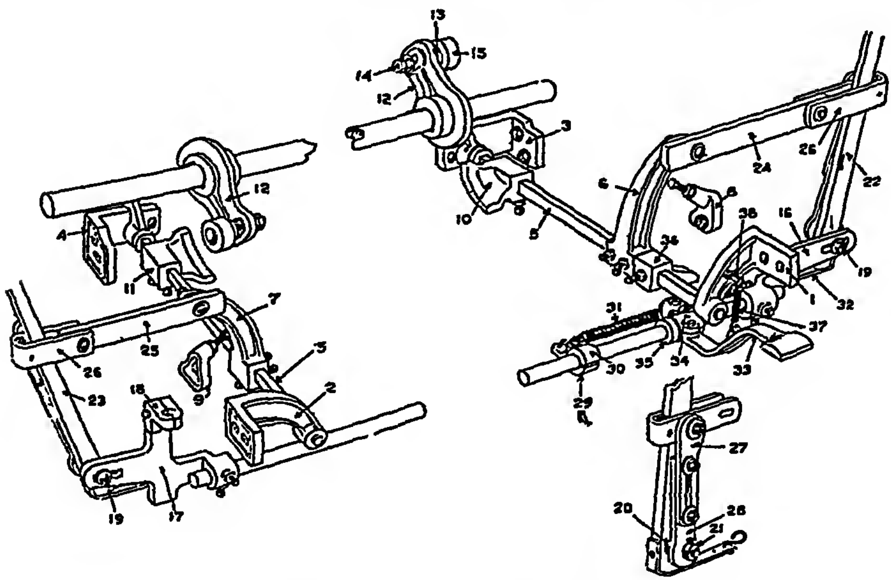


Fig 6 Picking motion connections and parts
(*Courtesy Crompton & Knowles Loom Works*)

in which the various parts are numbered The picking motion originates in the lower driving shaft, on which picking roll arm 12 is keyed, carrying picking roll 15 adjustable on the arm by means of a roll bushing, bolt, nut, and check nut. This lower driving shaft rotates and contacts, by means of the picking arm and roll, a picking shoe 10 (one on each side of the loom) on a picking shaft and thereby depresses this shoe. This transmits a short "whip" motion to picking shaft 5, which is transmitted directly to the picking sweep-arm 6, which is connected with the picker stick 22 by means of adjustable connector 24 and lug strap 26 The latter is held in a definite position in relation to the picker stick by means of parts 21, 28, and 27, known as the picker-stick stud and power strap parts The lug strap forms the connecting link between the picking arm and the picker stick which reaches upwards and contacts the shuttle through a lug and strap.

The operation proceeds as follows · The two picker arms and rolls 12 and 13 impart a short, whipping motion to the picking shaft which transmits the same motion to the picker sticks by means of the connections shown, imparting a throw to the picker stick, which transmits it to the shuttle, causing the shuttle to be thrown from one side of the loom to the other. Much depends on the proper adjustment of these parts and the smooth picking of the shuttle The power of the pick, meaning the force required to throw the shuttle across, is controlled or adjusted by the power strap. The higher it is set on the picker stick, the less power is given to the pick, and the lower it is set on the picker stick, the greater the power The power of the pick depends largely on the size of the shuttle and its weight, including the amount of yarn carried This is the latest method of picking and in days gone by many different methods have been used Since the motion is harsh and intermittent, it requires the careful adjustment which is one of the main duties of the loom fixer Occasional replacement of the picker stick and lug straps often becomes necessary.

Beating-up or Lay Motion

The lay, shown in Fig. 7, is connected with the upper loom shaft, known as the crank shaft, which imparts a forward and backward motion to the lay It makes one complete to and fro movement for every pick inserted The lay consists of a heavy crosspiece 20 supported by three lay swords 3, 47, and 22, which fulcrum on stationary bottom shaft 46 Means for adjustments are provided to level

the lay, particularly the metal race or race plate 18 on which the shuttle travels back and forth from one side of the loom to the other At each end of the lay are the shuttle boxes and their parts The reed sets across the lay, behind race plate 18 and hand rail 42 and shuttle guard 43 into back stay 36, which holds it and the hand rail or reed cap in place

In the center of the lay is found the center-filling stop motion, indicated by the opening at 37 to 39 The lay in oscillating forward and backward serves to let the shuttle pass and beat the filling, so introduced, into the cloth.

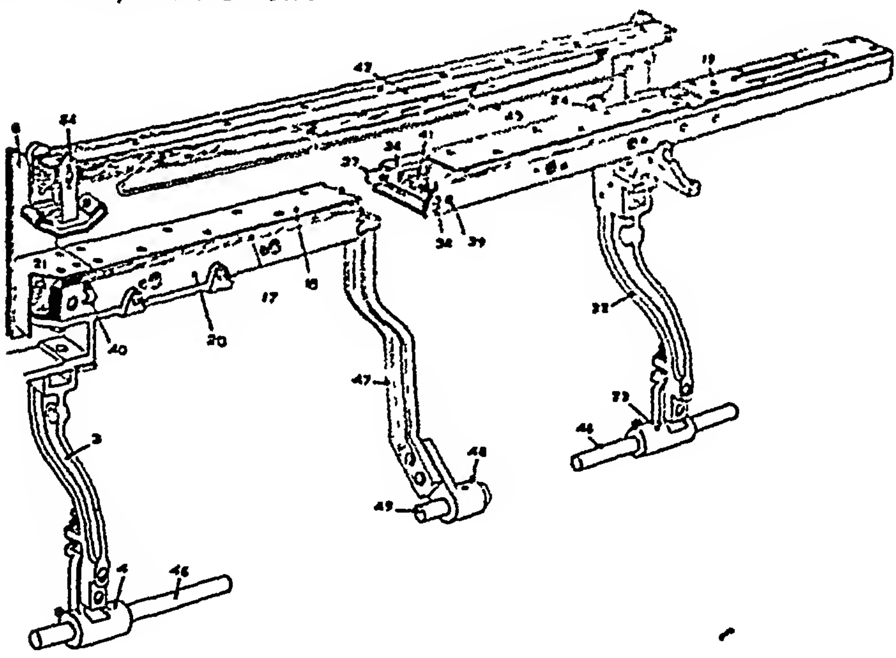


Fig 7 Details of lay connections
(*Courtesy Crompton & Knowles Loom Works*)

Letting-off Motion

The warp let-off on a woolen and worsted loom is comparatively simple, yet in every sense effective and satisfactory in most instances It is of the typical frictional let-off type and concerns the supply of warp yarn continuously, slowly, and uniformly to the loom Its assembly is shown in Fig 8

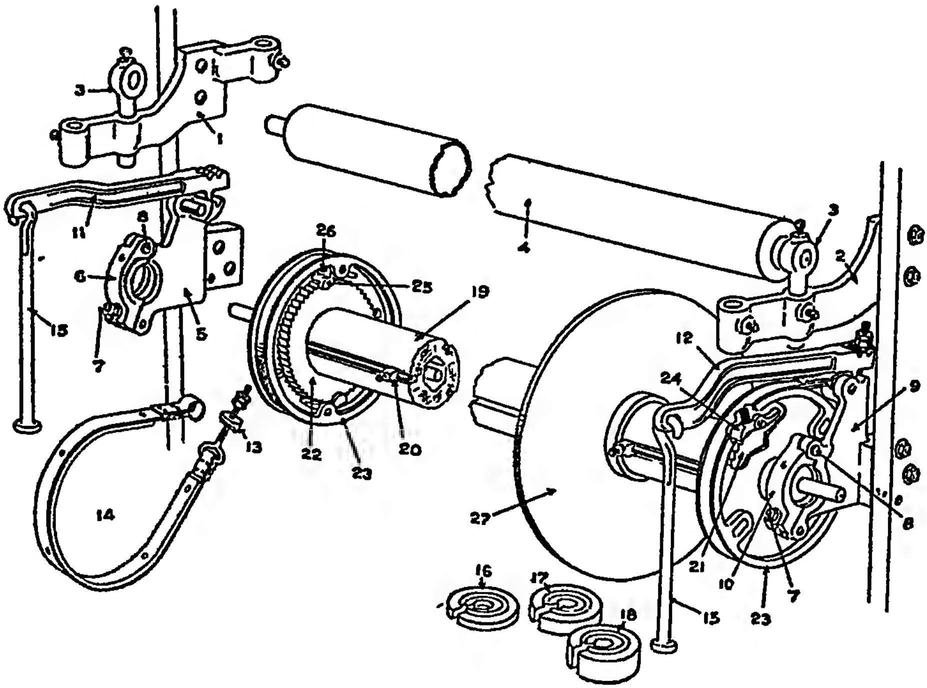


Fig 8 Assembly of warp let-off motion and parts

The warp beam consists of round wooden core 19, flange 27, ratchet 21 and 22 and the pawls 24 and 25 The assembly of the beam rests in bearings 6 and 10, provided with cap and clevis pin to secure its stationary position, but at the same time to permit easy rotation of the warp beam The ratchet and pawl arrangement serves when the beam and warp have to be backed up, when a pickout in the woven cloth has been made Friction is provided to the warp beam, the drum or beam head 23, by metallic friction band 14 covered on the inside with leather One end of the friction band is anchored on a steel stud, then laid around the smooth portion of the drum between grooves, and the other end is fastened by knife-edge washer 13 in one of the notches or grooves in friction lever 11 Suspended from this friction lever 11 is weight spindle 15, on which are placed the required weights 16, 17, and 18, laying on the floor in the illustration The amount of weight or friction required depends on the weight or size of the loom beam and how tight the weaver wants to run the warp The warp is passed over back roll 4, commonly known as whip roll, which rests in poppets 3, which

permit rotation or can be set-screwed down The beam heads are adjusted by means of a collar and set screw at the time the warp is beamed. The described arrangement is a friction let-off and when the warp beam is removed it is easily and quickly taken apart and replaced Adjustment of the friction and weighting of the warp are made by the weaver as he weaves the warp down

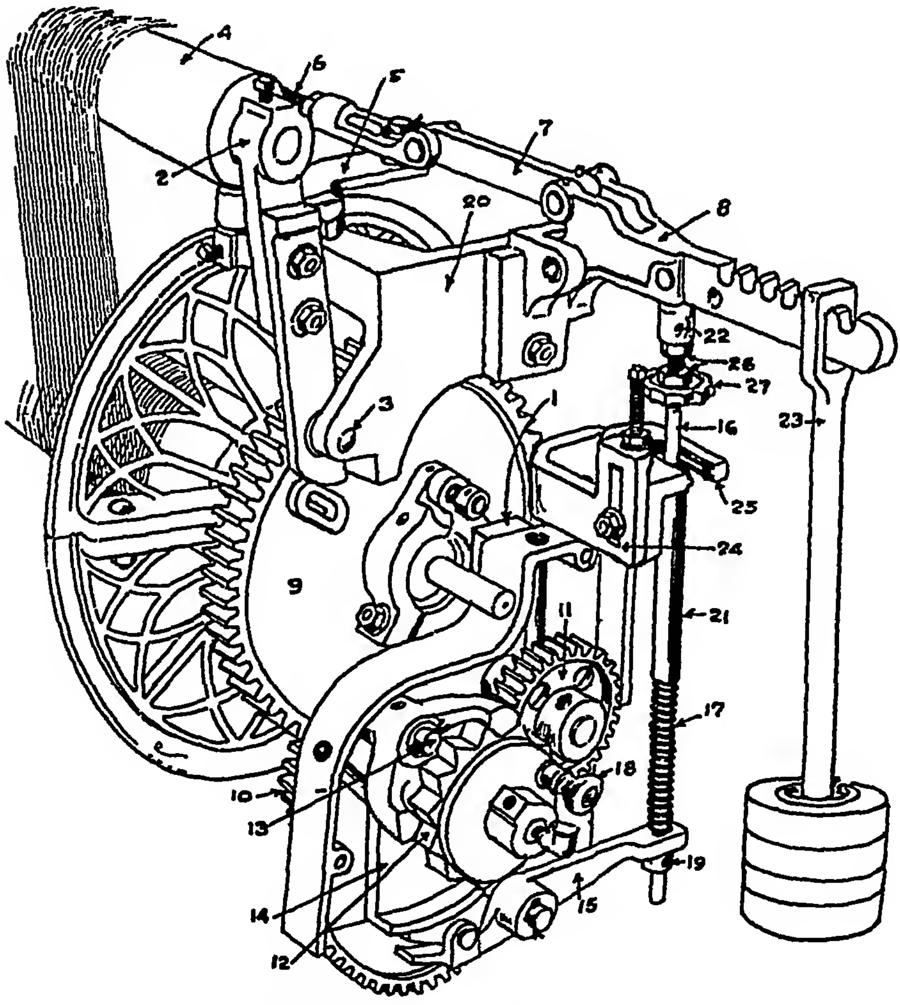


Fig 9 Full automatic let-off motion

Full automatic let-off motion. This let-off is completely automatic and has no connection with any moving part on the loom. A whip roll controls the letting off of the warp and provides the same with the necessary tension for weaving. Outstanding features of this let-off are

1 The whip roll mounting is such that there is no torsion nor twist to the warp In other words, the whip roll always moves parallel with the beam Further, this parallelism is easily adjusted or corrected

2 The tension supplied by the weights is so applied to the whip roll that it is positively uniform across the entire warp.

3. The tension weights are at one end of the loom in an out-of-the-way position.

4. The let-off operates on the escapement principle and, therefore requires no power to operate.

5 The let-off can if required be operated manually by means of the handwheel (18 in Fig. 9).

6 The oscillating whip roll acts as an easing motion and materially aids tender warps, reducing broken ends to a minimum

As shown in Fig. 9 the let-off consists of a pair of beam stands attached to the loom sides. Numeral 1 shows the left-hand beam stand to which the let-off mechanism is attached This stand contains a beam pocket provided with a cap and eye bolt for holding the beam bearing in position Vertically adjustable whip roll poppets 2 are pivoted at 3 on a stud in whip roll stand 20 Whip roll 4 is forced to the rear by means of pressure levers 5. These levers are joined by means of connector rod 6 in order that they will move in unison. Connector 7 joins connector rod 6 with weight lever 8 upon which lever the weights are suspended

The geared beam head or its equivalent 9 meshes with a pinion on gear 10, which in turn meshes with the pinion on the same shaft as gear 11 This in turn meshes with the pinion on the escapement wheel or ratchet 12

The free rotation of ratchet wheel 12 is prevented by means of the pawl or ratchet lever 14, pivoted as at 13 on an eccentric stud This ratchet lever has a concentric brake shoe, which is pivoted on the brake lever 15

The brake lever is attached by means of weight lever connector 16 to weight lever 8. Pressure is applied to brake lever 15 by spring 17, pipe 21, and adjustable anchor 25.

In operation, as the tension of the warp increases, the whip roll is slowly pulled forward thus raising weight lever 8 until collar 19

exerts sufficient pressure on the under side of brake lever 15 to release the brake, thus allowing ratchet lever 14 to oscillate and in so doing, the whole gear train will allow the beam to turn until a sufficient amount of warp is delivered to permit the whip roll to swing back, the weight lever to depress sufficiently so that collar 19 moves away from the brake lever, and thus allows the pressure of spring 17 to apply the brake and momentarily prevent the beam from turning This cycle of operation takes place automatically without attention. In the actual running of the loom it will be found that when the beam is full and a small amount of letting off is required, ratchet 14 will move very little for each pick, in other words, it may assume several positions for a single ratcheting By this arrangement it is obvious that the coarseness of the ratchet teeth has nothing to do with the exact amount let off at each pick The oscillating whip roll automatically maintains a constant tension on the warp and neutralizes any unevenness of the operation of the let-off

Take-up Motion

The take-up motion exists to take up the cloth just as fast as it is woven and to pass it on to the cloth roll It is located under the breast beam and is driven by the upper driving shaft of the loom There are three types in general use on woolen and worsted looms, namely

1 The ratchet-type take-up
2 The more recent worm-type take-up.
3 All purpose high-roll take-up

Ratchet-type take-up The ratchet type, in common use on the older nonautomatic looms, depends on the movement of an exchangeable ratchet, pushrod, and pawl driven from the crank shaft It is required that sand roller or take-up roll 27 in Fig 10 be rotated in exact accordance with the speed of the loom and the number of picks that are to be inserted into every inch of the woven cloth This is accomplished by means of a series of gears (as shown in Fig 11), which are carefully designed to perform this most important function of the loom On it depends the quality and uniformity of the woven cloth as far as the filling is concerned The number of teeth on the ratchet wheel often corresponds to the number of picks to be inserted into the cloth, assuming that one tooth of the ratchet wheel corresponds to one pick in the cloth In the ratchet motion the cloth passes over a high take-up roll,

which is covered with perforated tin or fine sandpaper, wound diagonally on the circumference of a metallic roll and provided with wooden plugs for tacking down. This roller rests by means of shafts in plain bearings and its rotation is controlled by a series of gears, such as are shown in Fig 10 From there the cloth passes three quarters to seven eighths of the way around the circumference of the take-up roll, over a guide roll 3 and down to the cloth roll 29, slotted for clamping the beginning of the piece

Worm-type take-up. The ratchet take-up has been largely replaced by the reverse worm type of drive Figure 10 shows a worm-driven lower roll take-up This take-up is always connected to the head drive and is automatically reversed with the head motion The weaver, therefore, when picking out automatically turns back the take-up an equal number of picks

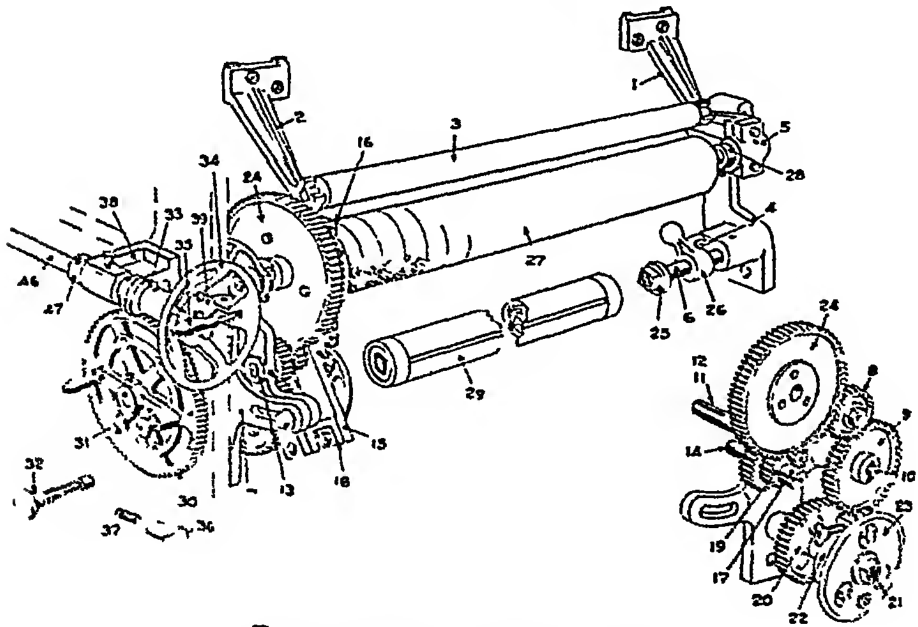


Fig 10 Worm-type take-up motion
(Courtesy Crompton & Knowles Loom Works)

In the lower roll take-up the cloth, after passing over the breast beam, goes around sand roller 27 from the front, around and up the back, covering a good part of the roll in order to be firmly held, and then over pressure roll 3 on down to shell cloth roll 29 The pressure roll is removable and all iron Sand roller 27 is driven by

a series of gears (24, 8, 9, 20), which have 75, 26, 44 and 41 teeth respectively in this particular arrangement On the sleeve of gear 20 is friction clamp 22 with adjustable spring and wing nut, which is connected with a hand wheel 34 on which worm gear 33 is attached and is changed for various pickages This gear is run by a worm (single or double) which is driven by the crank shaft This is a more positive take-up drive and gives better results

The hand wheel on the worm shaft serves the purpose, in case of a pick-out, to rewind the take-up roll to the point where the fell of the woven cloth is back flush with the reed. The cloth or cut when woven can be removed readily by means of stop handle 26 and sliding block 25 The cloth roll is provided with a slot and a wooden slat which permit clamping on of the cloth to get it started on the cloth roll.

All-purpose high-roll take-up. There is a take-up motion which combines the advantages of high- and low-roll take-ups, and by the use of pressure rolls and increased wrap of the cloth about the take-up roll, overcomes the necessity for the use of steel surfacing, thus aiding in the weaving of many fabrics containing silk and rayon decorations The purpose of the high-roll take-up is to minimize the slippage on the take-up roll, the cutting of rayon decoration yarns, selvage troubles, and temple cutting.

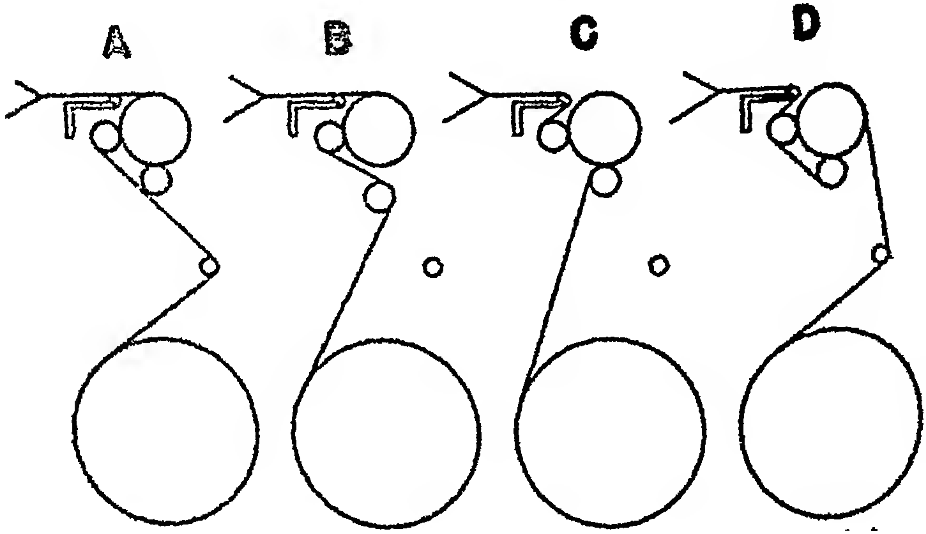
One advantage of the high roll, as compared to the low roll, is the short distance from the fell of the cloth to the bite of the take-up roll The cloth has less opportunity to contract and thus lies wider on the take-up roll. This means less strain on the temples

Up to this time low-roll take-ups have been preferable for several reasons. When a large amount of beat-up was necessary (as in high-sley high-pick gabardines), because of the greater distance from the fell to the bite on the take-up roll, damage to the cloth from steel surfacing or sandpaper coarse enough to hold was avoided to some degree, but not wholly. One cause of this damage is the tendency of the cloth to contract on the take-up roll at the beat-up Another cause is that all take-ups are so designed that the surface of the winding roll moves faster than the take-up roll; also many times it is necessary to have enough friction on the winding roll to help pull the cloth along. When this is true and it is necessary to pick out and let back the take-up, the greater speed of the winding roll reduces the tension between the winding and take-up rolls and thus allows the cloth to slip on the sandpaper or steel surfacing of the take-up roll. The use of two felt-covered pressure rolls changes this They not only hold the cloth without any help from the wind-

ing roll, but it is also possible to use a surfacing on the take-up roll which is smooth enough to prevent any damage even to silk or rayon decorations It is even possible to weave "hard beaten" cloths when passing directly to the take-up roll (as in example A of Fig 11), and thus reduce the strain on the temples.

The all-purpose take-up makes use of a chain drive from the take-up roll to the cloth roll, and thus reduces defects such as uneven cloth resulting from backlash in worn take-up gears

Figure 11 shows four methods of threading the cloth around the take-up roll and pressure rolls to the cloth roll.



The following is a tabulation of the distance between the reed when the lay is on front center and the line of contact of the woven cloth with the take-up roll is according to the four arrangements shown in Fig 11. It also gives the angle of wrap in each case

	Distance		*Wrap*	
	C-4 Take-up	*W-3 Loom*	*C-4 Take-up*	*W-3 Loom*
A Tropicals	12¼″	12⅜″	256°	237°
B Flannels	12¼″	12⅜″	256°	237°
C Gabardines (light)	18⅜″	18¹³⁄₁₆″	284°	295°
D Gabardines (heavy)	24⁹⁄₁₆″	25½″	261°	245°

Center-Filling Stop Motion

A center-filling stop motion will be used wherever cloth perfection is important because this type of filling-break indicator stops the loom on the pick when the break occurs and brings the lay to rest before reaching front center Therefore, two important advantages are gained over the side-filling fork, first, the reed stops before reaching the fell of the cloth which will prevent marking the fabric, and second, correction of the pick fault may be made immediately, for the loom stops before the harnesses change

It is true that with certain types of filling and also when the break occurs near the end of the shuttle flight, the stop motion fork may still be held up by the filling and so fail to stop the loom until the next pick, but conditions of this sort arise with any style of filling stop motion However, the center-filling stop motion is very sensitive if properly set, and failure to indicate the broken pick instantly is not common

The fork of the center-filling stop motion is located in an open well in the central portion of the race, the free end of the fork projecting directly toward the reed When the lay moves toward the "back center" position of the crank, the fork tilts upward through the warp far enough to allow the shuttle to pass underneath, and the filling, if intact, is laid under the fork With the beat-up of the lay, the fork drops downward upon the filling and is held from completing its downward motion by the grid effect of the warp supporting the filling against the light pressure of the fork In this condition, the fork holds the knock-off arm away from the knock-off lever.

The free end of the fork does not reach as far as the reed, and therefore the fork is pulled out of the shed just before the reed

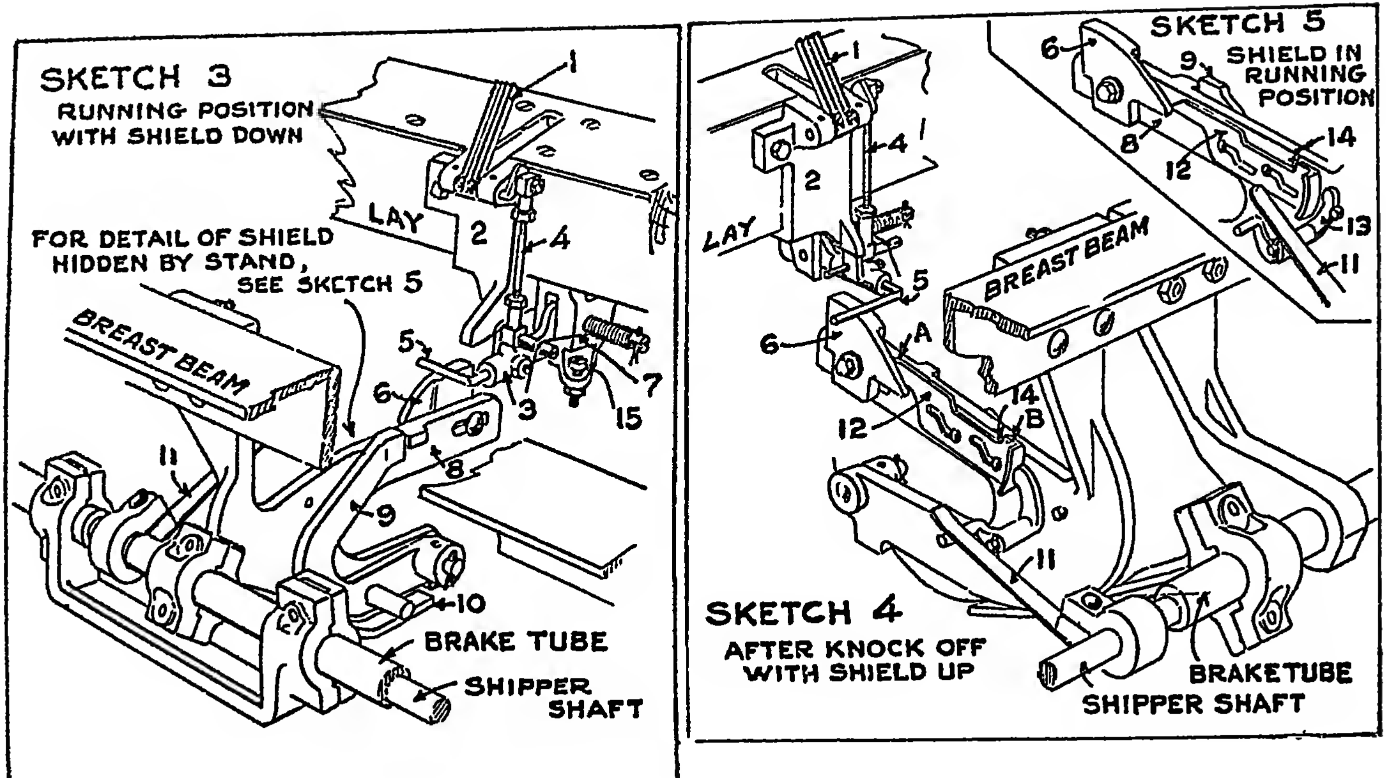


Fig 12 Details of center-filling stop motion

reaches the fell of the cloth for the final beat-up of the filling If no filling is present under the fork as the lay comes forward, the fork drops into its well in the lay, and, through a direct connection, the knock-off arm is moved into contact with the knock-off lever, which in turn contracts with the lever fastened to the shipper rod, causing the loom to stop

Assembly on the lay (See sketch 3, Fig. 12). Filling fork 1 is pivoted on stand 2 and is connected to lever 3 by connector 4 As the lay moves back and forth, knock-off arm 5 moves over the face of cam 6, arm 5 being held against the cam by spring 7 Fork 1 is therefore tilted upward as the lay goes backward and drops downward as the lay moves forward

Assembly on the breast beam Stand 8 is bolted to the breast beam The foot of the stand in contact with the face of the breast beam is equipped with adjustable screws so that the setting of the stand may be accurately adjusted in relation to the lay Knock-off lever 9 projects above the lug stop on stand 8 as shown in sketches 3 and 5, Fig 12. If as the lay comes forward there is no filling under fork 1, arm 5 will follow cam 6 and so engage lever 9, which, through lever 10 clamped to the brake tube, will knock off the loom

When the loom knocks off, spring 11 clamped to the shipper shaft pushes shield 12 (see Fig 12) back by the action of the double-arm, intermediate lever 13 The shield rises above the top of stand 8 and the top of knock-off lever 9 because of the shape of the cutout cam slots through which it is held to the stand, as shown in sketch 3 When the shipper is pulled on to start the loom spring 11 moves upward away from lever 13, thus releasing pressure against shield 12, which, however, remains up owing to the dwell in the cam slots guiding it On this first pick there is apt to be no filling under the fork and so if it were not for the shield, the loom would knock off The shield, however, remains up only for this first pick because advancing arm 5, after sliding along the edge of the shield and past knock-off arm 9, strikes the end of cutout 14 in the shield, pushing it forward and so down into inactive position as illustrated in sketches 3 and 4, Fig 12

Automatic Filling Replenishing Device

On an ordinary woolen and worsted loom, whenever the filling bobbin in the shuttle runs out, the loom is stopped by the weaver or it is stopped by the center-filling stop motion, just described Heretofore, it was necessary for the weaver to remove the shuttle from its box, extricate the empty filling bobbin from the spindle and re-

place it by a new bobbin or cop filled with the same yarn, from a filling supply board at the loom He was then obliged to thread the filling yarn through the eye of the shuttle, replace the shuttle in the box from which it was removed, and start up the loom. This entailed considerable time and work and delayed production every 12 to 18 inches of woven cloth When 2 or more shuttles or filling had to be so replenished the production loss was that much greater

To make the operation of woolen and worsted looms more nearly automatic and replenish the filling yarn supply *without* the removal of the shuttle and *without* stopping the loom at all, the automatic stationary magazine was invented This is a filling bobbin replenishment attachment, commonly known as the "magazine". It consists of five distinctly separate and intricate mechanisms referred to here as the magazine, the feeler motion or detector, the thread cutter, the color indicator and the thread holder

In woolen and worsted looms the magazine consists of 4 cells, which means 4 different kinds or colors of filling can be woven and replenished automatically It has a capacity of 34 full bobbins, that is, 8 or 9 bobbins in each cell The magazine is located on the side of the loom that has only a single box on that end of the loom This requires that there shall be not less than *two* successive picks from any one bobbin, as the shuttle must return to the drop box end before a change of shuttles is possible

The color indicator operated from the box lifter chain is the mechanism which assures that a bobbin of the right kind or color of filling will be placed in the proper shuttle It also makes it possible to retain an indication of the absence of filling yarn until the shuttle containing the nearly empty bobbin is again called into action The feeler, or detector, is the device which each time the lay comes forward, reaches through a slot in the metal binder and the front wall of the shuttle and feels the bottom end of the bobbin to detect the presence or absence of filling yarn

When the amount of yarn on the bobbin is sufficiently reduced, the feeler slips sidewise and this indication is passed to the magazine with the result that at the proper time, the empty bobbin is ejected through the bottom of the shuttle into a can A full bobbin from the correct cell in the magazine is now transferred to the shuttle in its proper position without slowing or stopping at the front-center position of the lay The bobbin is provided with 3 steel rings, which are held by strong spring clips in the shuttle

All this takes place instantly and at the time the lay is in a stationary front position

The thread cutter cuts and holds the filling end from the ejected bobbin It also serves to evoke an indication from the magazine, that

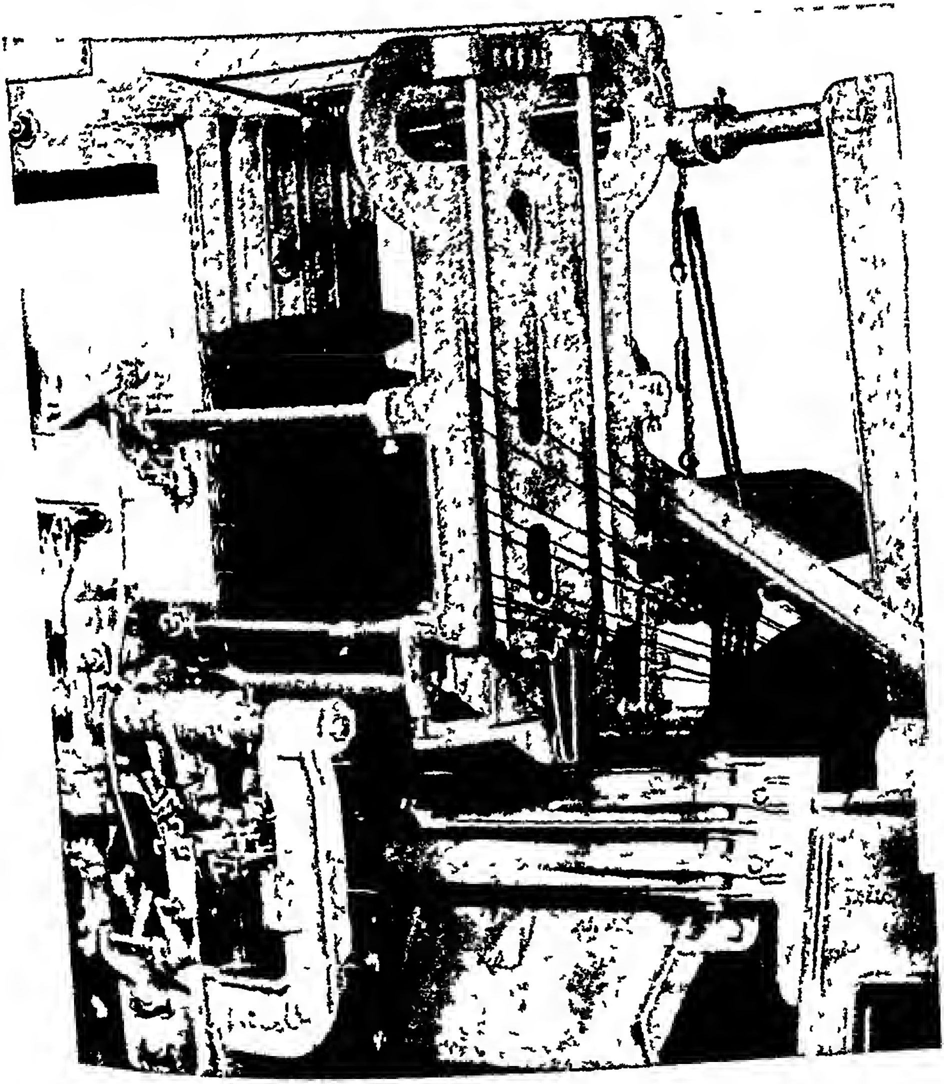


Fig 13 Automatic stationary magazine for filling shuttle replenishment. (*Courtesy Crompton & Knowles Loom Works*)

the shuttle is not properly boxed on the pick on which the transfer is to be made The thread holder serves to hold in reserve the filling ends from all the bobbins in the magazine Vibration set up by the operation of the loom causes the two gears between which the filling ends are held to rotate inwardly toward each other and thus take up any slack there

Figure 13 shows the automatic magazine in its details and fully charged with bobbins A complete description of all its parts, motions and adjustments is found in a booklet which can be secured free of charge from Crompton & Knowles Loom Works Due to its intricacy and the space required for a detailed description, it is omitted from this text

Warp Stop Motions

Two types of warp-stop motions are employed on woolen and worsted looms While they are not absolutely necessary, they are used on worsted warps of fine yarns and in goods where missing warp ends cannot be tolerated They serve the purpose of stopping the loom when a warp yarn breaks during weaving In other words, this device is the watch dog over the warp yarns, just as the filling stop motion sees that each pick is properly placed

The location of this stop motion is usually between the backroll (whip roll) and the lease rods, and nearest to the back or whip roll There are two types of stop motions in common use

1 The mechanical warp-stop motion
2 The electrical warp-stop motion

The electrical stop motion is preferred by some, others think the mechanical stop motion is more positive The preference lies with the mill superintendent and is purely a matter of what type of help is employed and what the loom fixers prefer and like to work on

Mechanical warp-stop motion The Crompton & Knowles mechanical warp-stop motion (Regan type) is simple in construction and operation quick to indicate a broken warp thread, and readily adjustable both in the indicating mechanism and drop wire capacity It is a very easy motion to maintain in perfect operating condition because of the very few parts and their simplicity Moreover, the entire indicating mechanism is above the warp, so that it is not in a position to be affected by the collection of lint, as is frequently the case where the indicating mechanism is located under the warp A further advantage in having the motion above the warp is the convenience for the operator

Experience has shown that it is advisable that a warp-stop motion

should be made an integral part of each individual loom and not dependent for operation upon agencies foreign to the loom itself By properly setting the driving cam the motion may be set to knock off the loom with the lay in any desired position. The Crompton & Knowles mechanical warp-stop motion (Regan type) is readily changed from one width of loom to another by replacing the oscillating rods and frame bars with others of the proper length

Wherever a large number of ends per inch in the warp are encountered, a motion having six, or occasionally more, banks or rows of drop wires is employed Conditions in this respect will naturally vary, depending upon the size of the warp yarn and the thickness of the drop wires used It is not necessary, however, to use all the rows available, but only a sufficient number of oscillating rods to take care of the number of wires which the warp demands

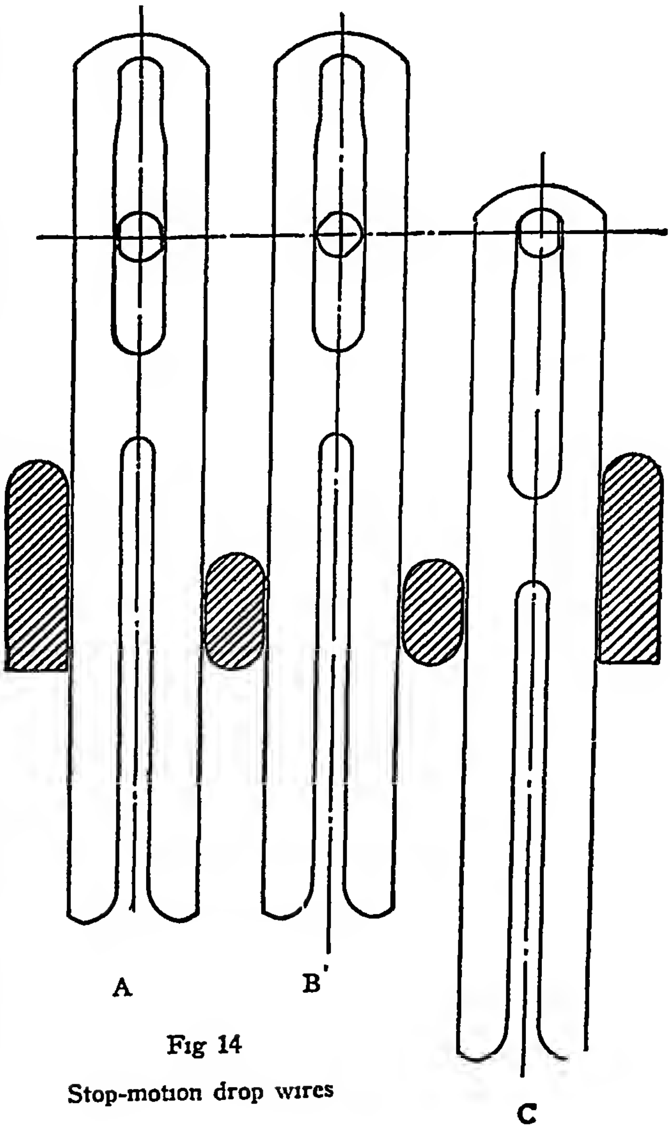


Fig 14

Stop-motion drop wires

One so-called "drop wire" rests on each warp thread (See Fig 14) The proper operation of the motion depends upon an interruption in the movement of an oscillating rod which passes through a slot in the upper part of the drop wire The oscillating rod is flattened on two opposite sides, and is free to turn to one side and then back into vertical position as indicated in Fig 14, A and B, which shows the normal operating position of the drop wire with the narrower upper part of the enclosed head opening held above the rod

When a warp thread breaks, the drop wire falls and the constricted head of the wire fits over the flattened sides of the oscillating rod, Fig 14, C, which is consequently prevented from turning, except for possibly a harmless slight bending of the drop wire under the strain of the driving spring This condition causes a trip to knock off the shipper handle and so stop the loom Below the warp and on each side of a row of drop wires are so-called frame bars or separator bars, which act to resist the twist of the drop wire when holding an oscillating rod, to keep the rows or banks of drop wires in proper alignment, and to a certain extent as a support for the warp under the drop wires

Electrical warp-stop motion The general principle of a warp-stop motion having been explained, it will require no repetition A so-called drop wire, of which there is one for each warp thread, will, if it falls due to breaking of the thread, completes an electrical circuit which will act to stop the loom

The drop wire and its relation to the drop wire bar is illustrated in Fig 15 In this diagram A shows the wire held up by a thread and B a wire which has fallen and has closed the circuit to stop the loom The wire and the bar act as a switch The drop wire bar which passes through the heads of each row of drop wires (each row making a "bank") consists of two members insulated electrically from each other The outer member of this

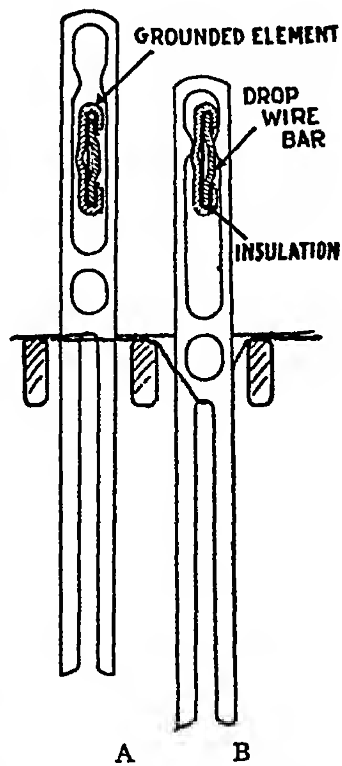


Fig 15 Drop wire and drop wire bar

steel bar is grounded to the loom frame The center member is extended beyond the outer one and is connected to the other center members of the bank.

The slot in the top of the drop wire as shown in Fig 15 contains two equal projections, one at each side. The action when the wire falls as shown in B of Fig 15, is to make these two projections touch the two sections of the indicator bar, the contacts being on opposite sides of the bar. It should be noted that the design of the wire and bar is such that the drop wire need not be placed on the warp in any particular position, that is, there is no back or front to the wire or the bar.

The drop wire bars or indicator bars are supported at each end Section heads are used to clamp the bars together and by this method from one to twelve bars may be mounted on the same support Changes and additions can be readily made It is easy to lower or raise the entire motion and hold it securely. Also the banks may be moved forward or backward with relation to the harnesses by varying the location of the section head clamping nuts on the threaded horizontal supporting rods

As previously stated, the outer members of the drop wire bars are grounded electrically to the loom side, for they are clamped firmly by the metal section heads The center members of the bars are connected to the electrical circuit by the threaded bolts and spacers The whole connection clamp is quickly removable because the ends of the bars are slotted It will be found that ordinarily this warp stop motion is sufficiently rigid without a center support on looms up to and including 56 inches between swords On wider looms, if there is considerable draw of the warp, a simple sheet-metal center support fastened to the back girt of the loom is furnished.

Protection Stop Motion

The protection motion on a woolen and worsted loom stops the loom and protects the warp from being broken when a shuttle gets caught in the shed and in case it does not complete its journey from one box to the other In such a case a smash would result, which is the reason why this device is sometimes called a "smash protector" The assembly of this device of the loom is shown in Fig 16

The assembly consists of two protection rod fingers (16 and 17) on the sides of the loom, which are pressed out when the shuttle reaches or is in either box If it does not reach either box or no

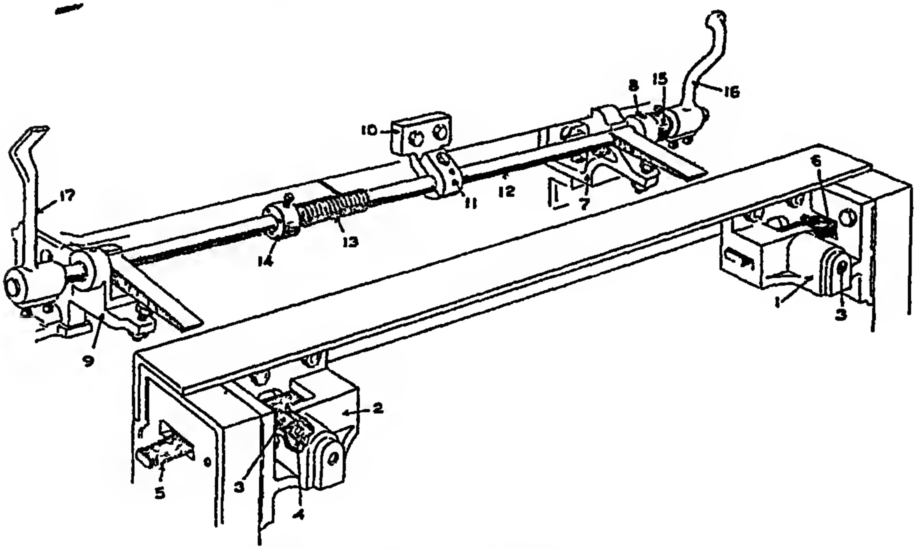


Fig 16 Assembly of smash protector
(*Courtesy Crompton & Knowles Loom Works*)

shuttle is in use at all, it is not pushed out, but keeps pressing by means of spring 13 against the binder leaf in the shuttle box There is a dog on each end of the protection rod, which fits perfectly into a knock-off lever stand, plunger, and spring (2, 3, and 4) Device 5 serves the purpose of knocking off the shipper handle, which keeps the loom running and stops it when moved by the dogs

Should the shuttle at any time get caught in the yarn shed and not reach its boxes the dogs on the protection rod are not depressed and engage their adjustment with knock-off levers 5 and 6 which disengage the shipper handle and apply the brake, stopping the loom almost instantly The length of the protection dogs keeps the lay and reed from smashing the shuttle and warp where it happens to be, which would result in costly repairs of the warp yarns and replacement of the shuttle itself The device is simple yet very effective, and saves many smashes and shuttles It is indeed a safety device on modern woolen and worsted looms, and requires little adjustment during operation

Types of American Looms

The W-2 loom. This is a twenty-harness loom, built along auto-

motive principles, with finished surfaces, roller bearings, and precision parts The following shuttles and their parts are available

Worsted.

16¾ in x 1¹⁵⁄₁₆ in x 1½ in (bobbin 8 in x 1⅛ in).
17½ in x 1¹⁵⁄₁₆ in x 1½ in (bobbin 8¾ in x 1⅜ in maximum)

Woolen

18 in x 2½ in x 1¹¹⁄₁₆ in (bobbin 8¾ in x 1½ in)

The W-2 loom is provided with either the high- or low-roll type of take-up, and either steel-band friction or full automatic let-off Loom beams of 24 inches diameter are now standard (28 inches maximum) The maximum width between swords is 96 inches This loom will weave the lighter weights of woolen and worsted men's and women's fabrics. One weaver can operate four, six, or eight of these looms, depending upon the character of the goods Twenty-four looms is the average loom fixer's unit Efficient loom speeds are dependent not only upon the width of the loom but also on the type of material being woven However, common speeds for 82-inch W-2 worsted looms are 134 and 142 picks per minute The W-2 loom is now available in the following basic constructions

Automatic worsted	2 x 1 and 4 x 1 box
Convertible worsted ·	4 x 1 box automatic and 4 x 4 hand-fed
Automatic woolen	4 x 1 box only

The W-3 loom This loom provides for twenty-six harnesses and is built stronger and heavier than the W-2 loom It has precision parts, finished surfaces, and is roller-bearing equipped The following shuttles and their parts are available

Worsted

16¾ in x 1¹⁵⁄₁₆ in x 1½ in (bobbin 8 in x 1⅛ in)
17½ in x 1¹⁵⁄₁₆ in x 1½ in (bobbin 8¾ in x 1⅜ in maximum)

Woolen

18 in x 2⅛ in x 1¹¹⁄₁₆ in (bobbin 8¾ in x 1½ in)
19½ in x 2⅛ in x 1¹¹⁄₁₆ in (bobbin 10⅛ in x 1½ in)

Three types of take-up are available · high roll, low roll, or the so-called "all purpose," which is a high-roll take-up A 16-inch diameter roll of cloth can be wound on the low-roll take-up, 19-inch on the high roll; and 20-inch on the all purpose These looms are built up to the maximum width of 120 inches between swords The let-off can be either steel-band friction or full automatic The standard loom beam is 24 inches in diameter (30 inches maximum) The loom will weave any woolen or worsted fabric that the trade will require Four, six, or eight looms per weaver is a common occur-

rence An average loom fixer's unit is twenty-four looms As in the case of the W-2 loom, the efficient speed of the W-3 loom depends upon the width of the loom and the character of the cloth being woven Speeds of 134 to 140 picks per minute on 82-inch looms are common. The W-3 loom is available in the following basic constructions

Automatic worsted	4 x 1 box only
Automatic woolen	4 x 1 box only
Convertible worsted.	4 x 1 box automatic
	4 x 4 box hand-fed
Convertible woolen	4 x 1 box automatic
	4 x 4 box hand-fed
All-purpose worsted	4 x 1 box automatic.
	4 x 4 box hand-fed
	4 x 2 box automatic filling mixing (one kind of filling only)
All-purpose woolen	4 x 1 box automatic
	4 x 4 box hand-fed
	4 x 2 box automatic filling mixing (one kind of filling only)

4 x 1 box automatic loom This is the standard type of loom There is a four-cell shuttle box on the head end and a single-cell box on the magazine end Four types or colors of filling can be woven automatically No less than two picks can be taken consecutively from any one shuttle because of the single box on the magazine end

Convertible loom This loom can be operated 4 x1 box automatic as described above or the magazine can be turned back or removed from the loom and a four-cell shuttle box substituted in place of the single-cell box on the magazine end With four-cell shuttle boxes on each end, as many as seven shuttles can be operated pick and pick, and is, of course, hand-fed

All-purpose loom The W-3 loom is now available with "all-purpose construction" If complete equipment is purchased with this loom, it can be operated in the following different ways 4x4 box hand-fed, 4x1 box automatic, or 4x2 box automatic (one kind or color of filling only) With the final arrangement, three, four, or five shuttles can be run consecutively, single picks, for mixing one type or color of filling All cells of the magazine are used as a common reservoir for replenishing filling for all the shuttles. This is not a pick-and-pick automatic loom

Chapter 17

WOOLEN AND WORSTED WEAVES

THE manufacture of woolen and worsted fabrics of all descriptions requires a knowledge of textile design. A piece of cloth can be compared to a bridge, the design of which requires an engineer and draftsman before construction. In the woolen mill, the designer is the engineer or draftsman. Upon him rests the construction of a cloth, its composition, or weave structure, the amalgamation and combination of such weaves, and the mixing and blending of colors. Hence, a textile design may be compared to a blueprint of a cloth, and represents the specifications of a fabric. On this design or pattern, planned ahead of actual production, depends the success of any line of fabrics and, subsequently, that of the mill itself.

A study of weaves involves their application to various kinds of yarns, constructions, and weights. Each mill keeps its own records of patterns, designs, drafts, and samples made. The designer is technically trained in all practical mill operations and is required to possess a natural sense of color harmony. The finished plan or design of a fabric is usually so complete that any boss weaver, finisher, or any department head knows or can learn from the layout exactly what is wanted without further questions. He specifies all details concerning the composition, finished appearance, and weight of a fabric.

Methods of Describing Weaves

Use of design paper. In order to be able to do this preparatory work intelligently and thoroughly certain means are placed at the designer's disposal. One of his most important tools is cross-section paper, also known as "squared" or design paper, on which he designates the weave or combination of weaves, the drawing-in draft, and the sequence and arrangement of the harnesses of a loom. The design paper consists of fine and heavy black or blue lines, running at equal distances both horizontally and vertically. The paper comes in large sheets or in pad form, depending on the size required or most convenient.

The object in using this paper is to portray the method or system by which the individual warp and filling yarns will interlace to form the weave of a fabric Figure 1 shows the most common woolen and worsted weaves, and gives an illustration (somewhat reduced) of the paper used and how the weaves are designated on it In order to understand this more clearly, it should be explained that the spaces between the fine vertical lines represent the individual warp threads or "ends," whereas the spaces between the fine horizontal lines represent individual filling threads or picks in a cloth. The occasional heavy lines merely aid in counting the spaces more readily, being spread eight, ten, or twelve squares apart in either direction

Since the wrap or "ends" run lengthwise in the fabric or loom and the filling picks are inserted horizontally and at right angles to the warp, there are only two possibilities of interlacing. Any individual warp thread can only lay on top or over the filling thread, or under it. To indicate which it is meant to do on design paper, the square can be left blank or it can be filled in with a cross or completely filled in with pencil or ink If the square is left blank, it means—to all designers—that the particular warp yarn is to lie below the particular filling pick at that intersection. If the square is filled in with a cross or completely filled in, it means that the particular warp yarn is intended to be raised over or lie on top of the particular filling yarn or pick. Hence, all crosses, dots, circles, or other marks in any square in the design paper represent raised warp threads, unless otherwise specified by the designer This system of designation is universal among textile designers and technicians, and is used in the following pages

Verbal designation of weaves. As an alternative to using design paper, weaves are expressed in other ways in conversation and in writing. The warp and filling threads are designated as being "up" or "down." Hence, the plain weave could be stated in a letter, for instance, in the manner $\frac{1}{1}$. The word "up" or the figure above the line, indicates the number of threads raised on each pick, while the word "down" or the figure below the line, designates that such threads should be lowered for the filling to pass over. For

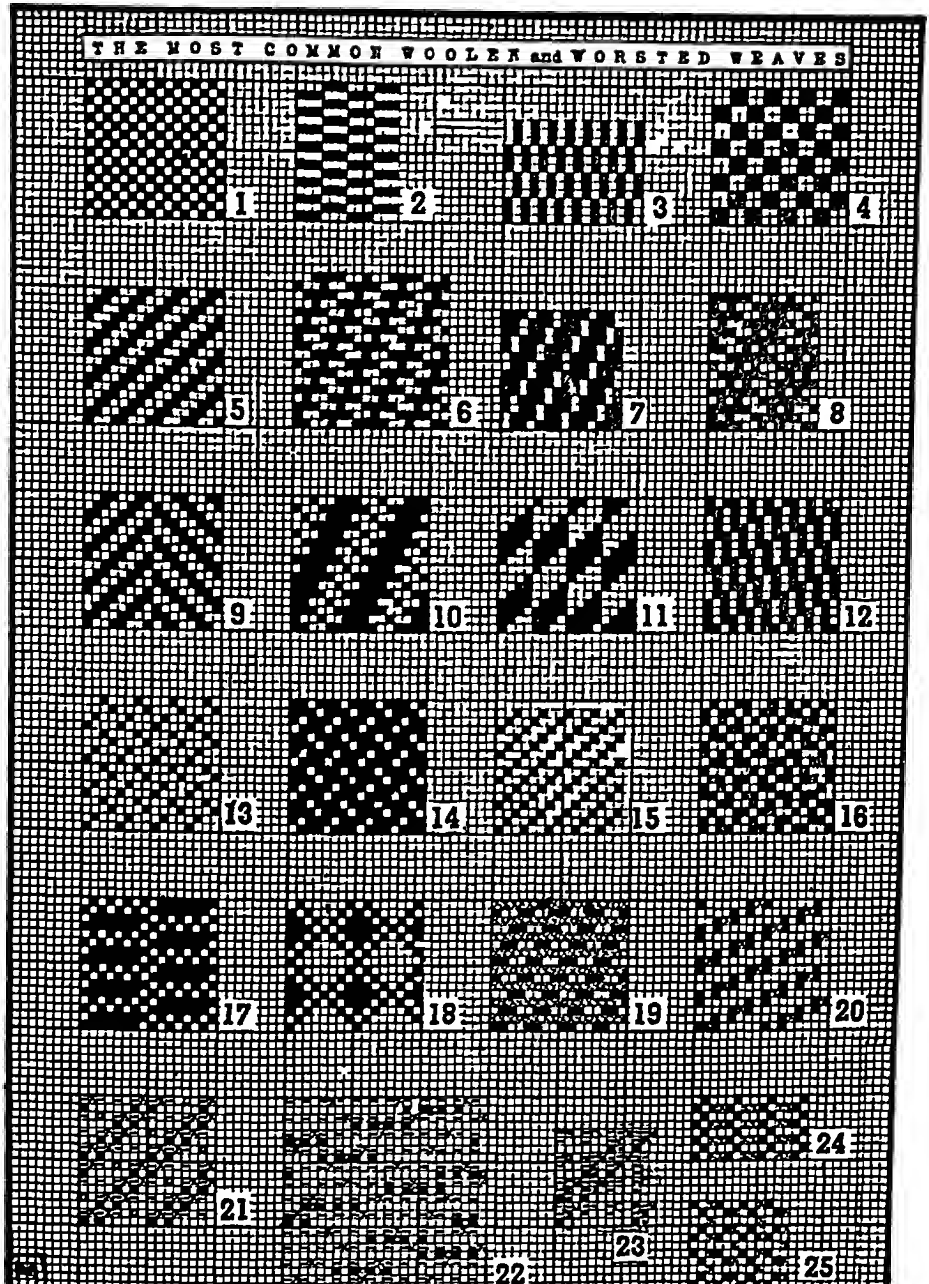


Fig 1 Twenty-five common weaving designs

instance in the case of the basket weave, it can be stated as a 2 by 2 basket, or a $\frac{2}{2}$ basket This method of description applies very well to the simple weaves but when it comes to twills and satins, stating just the threads up and down is not sufficient The class or kind of weave and, in other cases, the degree of twill and so forth should be given to clarify what is meant Nevertheless, this does constitute another method of indicating the weave of a cloth, aside from drawing it out on design paper which, with the elementary weaves, is not ordinarily necessary

The Plain Weave

To illustrate this system by the simplest weave used in woolen and worsted fabrics, known as the plain, tabby, or cotton weave, reference is made to design 1 in the weave chart (Fig 1) In this weave there are only two single movements, one thread is up and one thread is down, or all even-numbered warp threads are up and all odd-numbered warp threads are down, and vice versa If this weave is made in contrasting colors, say white warp and black filling or vice versa, it would look exactly like the design pictured and resemble a checkerboard Of course, it must be borne in mind that the sequence of this method of interlacing cannot be broken or interrupted in any way, without interfering with the continuity or appearance of the weave throughout the width and length of the cloth

The extent to which the weave is carried out depends generally on its repeat in both vertical and horizontal directions The plain weave in the illustration is extended to sixteen ends by sixteen picks, simply to show its appearance in both directions It is not necessary to carry it out as far and careful examination of the first, second, and third end (warpwise or vertically) will prove that the first two ends act exactly opposite with respect to the filling i e, where one is up (that is, over the filling or filled out) the adjacent one is down or under the filling However, the third warp thread from the left acts exactly the same as the first thread, the fourth end acts like the second, the fifth like the third and first, and so on Therefore, the plain weave really repeats itself every two ends by two picks This is the simplest method of interlacing the warp with the filling yarns and requires a minimum of two harnesses, shafts, or leaves in the loom to weave it Referring to design 1, the first pick

at the bottom, the warp threads one, three, five, seven, etc are down and threads two, four, six, eight, etc are raised in that shed At the next pick, threads one, three, five, seven, etc are up and threads two, four, six, eight, etc are lowered

This weave is employed a great deal in woolen and worsted fabrics, from the finest challis to the coarsest coating or carpet It gives an exceedingly strong, firm cloth and a smooth surface, but gives the cloth a harder feel and less elasticity than fabrics woven with other weaves This weave is commonly employed where a flat texture or face is desired Of course, the nature of the yarn, the stock, the direction of the twist, and the closeness or openness of the cloth construction will affect the surface appearance of the finished fabric That is true of all weaves

Derivatives of the plain weave There are three types of weaves derived from the plain weave which find much use in woolen and worsted fabrics They are the *warp rib-weave*, the *filling rib-weave*, and the *basket weave* The first two as a group are known as "rib" weaves, because they form ridges in the cloth in either warp or filling direction The simplest way to form rib weaves is to weave two or more threads together as one For an illustration, refer to design 2 in Fig 1 This is known as a 3 x 3 *filling rib-weave*, meaning three warp threads weave as one with single picks only, and that the rib thus formed would run in the direction of the warp They are made with two, three, or four threads, depending on how much of a rib is desired The three warp threads in each group can be drawn on individual heddles on each of two harnesses, or three ends into one heddle on each harness The latter method may cause rolling of the ends over and under each other, which is objectionable in clear finished worsteds, for instance These can be alternating, regular, combined, or fancy, and constitute the source of many interesting rib effects in dress goods and men's wear

The next illustration or design is number 3 in Fig. 1 and constitutes a *warp rib-weave* Here each warp yarn floats over three picks, alternating over or under and repeating, forming a rib or ridge in the direction of the filling in the cloth The one illustrated is a 3 x 3 warp rib weave They can be made in all even or uneven combinations such as 2 x 2, 3 x 3, or 3 x 2, 4 x 1, etc There is no limit to such combinations These rib weaves are valuable in that they alter or break up the monotony of the plain weave and find

considerable use in striping goods with or without color and in combination with other weaves as well

Design 4 constitutes what is commonly referred to as a *basket weave* It is a derivative of a plain weave in which two or more adjacent warp and filling threads are raised and lowered together as if they were a single thread It produces a checkerboard effect, more pronounced than in the plain weave. The size of the squares depends on the number of threads working together The basket weave illustrated in design 4 is designated as a 2 x 2 basket (two warp threads work with two filling threads) They can be made larger, such as 3 x 3, 4 x 4, 6 x 6, and 8 x 8 threads They can also be made unbalanced by using different numbers of threads, such as 8 x 4, 2 x 1, 4 x 2, etc , giving unlimited possibilities Color can be made to play a part in these checks and many pleasing effects are obtained The warp threads working side by side can be drawn on separate shafts or on the same shaft In coarse woolen goods or closely set worsteds, it may be necessary to draw the grouped warp yarns into one heddle to prevent chafing Because several picks are introduced into the same shed a binder thread at each selvage must be used to prevent the filling from being drawn in during weaving This is also true in the warp rib-weave

In order to get squares of the same width and length, the same number of ends and picks per inch should be used If this cannot be done, and the warp is set closer than the filling, a weave having more warp than filling threads working together is used to prevent the squares from becoming oblong or unbalanced Squares of different or alternating sizes can be woven in the same pattern also, providing unlimited combinations These weaves are used extensively in women's dress goods and coatings as well as men's wear Of course, these derivatives of the plain weave become looser owing to the larger number of threads that are working in a group

The Twill Weave

The twill weave in its various ramifications is the one most commonly employed in woolen and worsted dress goods, coatings, and men's wear. In all its forms the twill weave is distinguished from the plain weave in that it develops a more or less pronounced diagonal line in the cloth The twill weave is characterized by the fact that the float of each filling thread is advanced one warp-thread to the right or left of the preceding filling thread, assuming, of course, that all the floats are alike Twills can be classified in various

ways and the following list covers the many different kinds used in the woolen and worsted trade.

1. Balanced twills or even twills
2. Warp-effect twills } Uneven twills
3. Filling-effect twills }
4. Steep twills: 52°, 63°, 70°, and 75°
5. Reclining twills: 38°, 27°, 20°, and 15°
6. Right- and left-hand twills.
7. Pointed or herringbone twills
8. Broken or reversed twills.
9. Corkscrew twills.
10. Interlocking twills
11. Offset twills
12. Undulating twills
13. Diversified, combination, or fancy twills

The simplest twill that can be made is a three-harness twill, often called a prunella or filling-face twill. These names vary according to the nature of the material or the relation of the warp and filling in the construction of the cloth This twill is illustrated in design 15 (Fig 1) Close examination of this weave discloses that it is a 45° twill and a "filling face twill" In written form it is expressed as a $\frac{1}{2}$ 45° twill, or a 1 up and 2 down 45° twill It is a 45° twill because it advances one end to the right with very pick It is a "filling effect" twill because two thirds of the filling shows on the face of the cloth and only one third of the warp, proportionately No matter from where one starts to read the weave, it is a one up and two down The weave repeats every three ends and three filling picks, but is drawn out to 15 x 15 to show its appearance and effect in a cloth which has the same number of ends and picks per inch

It can be noted that the first warp thread at the lower left corner is filled in, meaning that it is raised above the first filling pick The first pick from the bottom passes under the first warp thread and over the next two warp threads (to the right) and repeats that way across the width of the fabric The second pick directly above (horizontally) passes over the first warp thread and under the second and over the third and fourth and so on repeating The third pick passes over warp threads one and two, and under warp thread three The next pick is just like the first, and the fifth and sixth picks just like the second and third, respectively Looking at the whole design, the twill is complete, continuous, and unbroken

According to the kind of cloth it is used in, design 15 makes a very fine and delicate diagonal If the warp ends are made of fine worsted yarns and crowded together, the twill angle will become steeper without employing a steep twill weave. If the picks are increased and laid closer together in the loom the twill line becomes reclining The twill as it is shown is a right-hand twill (the usual way of making it), because it runs from the left to the right If it is reversed and made to run from right to left, it becomes a left-hand twill, which is less common in the wool trade.

To make this twill a warp twill or "warp effect" twill, its formula, 1 up and 2 down, is reversed to read 2 up and 1 down The reversal will bring the warp to predominate on the face, whereas it showed on the back of the cloth previously

Such twilled fabrics are generally more lustrous, softer, and more pliable than fabrics made with a plain weave In weaving, twill cloths take the picks much more easily than the plain woven fabrics, hence they can be set closer in the warp and reed, making the cloth heavier, everything else being equal.

Balanced or even twills The most common twill employed in all types of serges, gabardines, overcoatings, etc. is the cassimere, shalloon, or common twill This weave is illustrated in design 5 (Fig 1) It is designated as the famous 2 up and 2 down 45° twill, which makes it a "balanced twill" because one half of the warp and one half of the filling show on the face Also, because it is made with an *even* number of risers and sinkers in the weave pattern, it is known as the "even twill" It requires a minimum of four harnesses in the loom and repeats on four ends by four picks Attention is called to the angle of the twill, which is 45° with the horizontal It is continuous and unbroken

In designing this twill or making up other twills, one should always begin in the lower left-hand corner of the design as is done in design 5 It is noted that the 2 up and 2 down 45° twill shown commences with the first warp thread (from the bottom) up on the first two picks, down on the next two, up for the next two picks, and so forth as far as one wishes to go The second warp thread commences with 1 down and 2 up, then 2 down, 2 up, and so forth In other words, the raised part, which forms the twill line or diagonal, is always advanced one pick This is characteristic of all 45° twills The third warp thread commences with 2 down, then 2 up and 2 down, showing again that the twill has been moved up again one pick The fourth warp thread starts with one end up for one pick,

then down for two picks and up again for two picks and so forth up the line The next or the fifth warp thread operates exactly like the first, the sixth like the second, the seventh like the third, and the eighth like the fourth end, and so on Hence, the weave repeats on four ends and four picks as indicated This is one of the most important weaves in the twill family

Effect of yarn twist on twill The direction of the twill and the twist in the warp and filling yarns have a great influence on the appearance of the twill in the cloth In order to make this perfectly plain, it is necessary to come to an understanding about the direction of twist in single woolen or worsted yarns Single-wool yarns are generally twisted to the left, the now termed S twist, whereas single reverse-twist yarns are generally twisted to the right or the now termed Z twist (A S T M designations) Two-ply yarns usually have an opposite twist to the single-ply. Hence, an S-twisted warp yarn used running from left to right in a warp twill, will make the twill more prominent If an indistinct warp twill is wanted, a Z-twisted warp yarn should be used. In other words, in twill fabrics the clearness and prominence of a twill line are accentuated if their direction is opposite to the surface direction of the twist of the yarn, with the reverse conditions obtaining for indistinct twills The whole relation of direction of twill to direction of twist in the warp and filling yarns is summarized in Table 1

TABLE 1
EFFECT OF YARN TWIST ON TWILL LINES

Direction of Twill	*Warp Twist*	*Filling Twist*	*Effect in Cloth*
*Left to Right	S	S	warp twill sharp
Right to Left	Z	Z	warp twill sharp
*Left to Right	Z	Z	filling twill sharp
Right to Left	S	S	filling twill sharp
Left to Right	S	Z	twill distinct
Left to Right	Z	S	twill indistinct
Right to Left	S	Z	twill indistinct
Right to Left	Z	S	twill distinct

* Most common conditions.

In practical work, of course, these conditions are greatly modified by the quality of the wool, the size, character, and turns of twist in

the yarn, whether it is single- or double-ply, closeness of the sley or "set" and also the finish of the goods Another circumstance must be considered If the twill runs right and left alternately and it is desired to have them equally distinct, right twist must be used for the warp yarn in the left twill and left twist in the warp yarn for the right twill. These points are very important in actual practice and are often the deciding factor between satisfactory and unsatisfactory goods, high quality appearance, and so forth.

Steep and reclining twills. While this variety of twill (also known as regular twill) is usually at 45° with the horizontal and advances one thread to the right or up until a full repeat has been obtained, there are other types that depart from this method and angle of diagonal They are the "steep" twills in one case and the "reclining or flat" twills in the other. The *steep twills,* as the name would imply, are twills that are steeper than 45° and run more toward the vertical These twills are formed when the warp float or twill line is advanced two or more picks instead of only one above the float of the preceding thread as is the case in the common 45° twill and brings the twill line nearer the perpendicular. Steep twills are exemplified in Fig 1 by designs 6, 7, 8, and 10.

The diagonal lines in steep twills are closer together, but frequently, owing to the filling floats on the back, are more prominent than the regular twills They are commonly employed in whipcords, uniform fabrics, tricotines, gabardines, and other women's and men's wear fabrics. These steep twills are made by advancing the twill float by two, three, or four picks on each successive end as is clearly demonstrated by the twill angle diagram (Fig 2) According to this figure, they are termed 63°, 70°, and 75° steep twills, advancing two, three, and four picks respectively. The 52° is a combination of one and two advances, but is not commonly employed For instance, design 7 is a 5 up and 2 down 63° warp effect twill Again, design 10 is a 7 up 1 down, 1 up 2 down, 1 up 2 down, and 1 up 1 down 63° fancy twill. Other 63° twills in Fig. 1 are designs 6 and 8

If a regular twill having an even number of shafts, say ten, twelve, or sixteen, is selected for the construction of a steep twill, only one half as many threads are used and hence, only one half as many shafts are needed On the other hand, if a regular twill has an uneven number of shafts, the resulting steep twill will have the same number of threads or shafts in the pattern Again, a steep twill with warp floats using three picks at each succeeding thread

requires only one third as many shafts as are required for the base weave, providing the base weave is divisible by 3. Where the number of shafts of the base weave is not divisible by 3, then the resulting steep twill will require the same number of shafts as the base weave.

These weaves can be made with long- or short-float twill lines, making them more or less prominent. The twill line, of course, is affected by the "set" or the sley of the cloth, that is, ends and picks per inch. If the set of the cloth is balanced the twill will run exactly as planned. If the warp is closer set than the filling, which is very common, the twill will be steeper than before. If the yarn sizes differ or are changed, the twill angle will also change to some extent. Hence, caution is required here, to prevent radical changes in the character and face of the goods when changing weaves or yarns.

The reclining twill is used only occasionally and for special purposes. These twills decline away from the 45° line and come closer to the horizontal. The same theory applies as in creating the steep twills, only in the opposite direction. When two moves or ends are skipped it becomes a 27° reclining twill; when the twill line is retarded three it becomes a 20° declining twill; and when a move of four is made it becomes a 15° reclining twill (see Fig. 2).

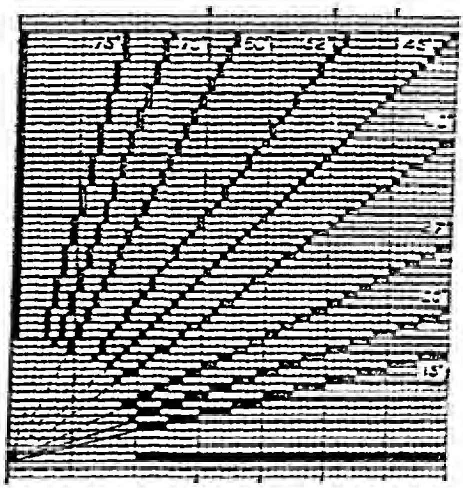


Fig. 2. Degrees of twills.

Pointed and herringbone twills. The term "herringbone" twill is applied to twills in which a sharp break occurs when the twill is reversed, especially when it runs for a considerable length before it is reversed. An illustration of such a twill is shown in design 9 of Fig. 1. Note in the design that a 2 up and 2 down 45° twill is employed, which runs one way for eight ends and is reversed for eight ends. Twills of longer floats than this, all variations and combinations can be employed here. Such weaves are common in ladies and men's suitings and coatings.

The pointed twill is very similar to the herringbone, in fact many mill men draw no distinction between the two in that the twill is

reversed without making a break or that it is reversed after it is allowed to come to a point This system forms the basis for damask diamond, zigzag, and honeycomb weaves, the latter of which is illustrated in design 18 of Fig 1, and gives wide opportunities for matching fields, squares, and checks created by weave only When colors are applied many interesting and vivid contrasts can be originated The pointed herringbone effect can be created with a twill chain and a pointed drawing-in draft (see designs) The twill in a herringbone weave can also be arranged to bring the points at the side of the design The pointed twill patterns have the general defect that the float at the apex is nearly double that of the other floats When it is important to have them short and practically uniform, risers are removed or inserted at that point Of course, this increases the number of shafts required in the loom

Broken or reversed twills. By breaking the twill line or practically reversing the direction at intervals in regular or irregular fashion, many attractive patterns can be created The twill can be reversed in either the warp or filling For instance, a 2 up and 2 down twill can be reversed every two warp threads and while the warp threads still weave two up and two down, the reversing of the twill causes every alternate pick to interlace the warp in plain weave order If the twill is reversed in the filling, the latter becomes more prominent than the warp, which is stitched (bound) more closely This applies to the balanced twills only These weaves are used in woolen friezes as they show no twill at all

Very interesting designs can be created by rearranging the parts of a twill so that two groups of threads, with the twill running in the same direction, alternate with two groups running in the opposite direction and also, by reversing the twill in accordance with selected motifs The latter gives ladder effects and crisscross twills, commonly employed in fancy worsteds

Corkscrew twills The peculiar feature of corkscrew or double twill weaves is the combination of two or more distinct twill lines, which may be of different colors They are also called diagonal ribs and employed in corkscrew fabrics such as spat goods woven of fine worsted yarns They are usually set closely in the warp and require manifold drawing-in drafts A typical corkscrew weave is shown in Fig 1, design 12

Corkscrew weaves can be made by reversing, deflecting, and waving or undulating the twill line. They may be developed with warp

as well as with filling floats The twill can be run alternately to the right and left in order to bring about an undulating effect suitable for stripes in worsted goods

Interlocking and offset twills Interlocking twills are used extensively to obtain wide diagonal effects with a relatively small number of harnesses in the loom They also permit an unlimited variety of special designs by interlocking weaves in the warp and filling as well as by bringing a ground weave on alternate picks They are also used to increase the filling absorbing capacity of a weave Any change in position produces a new effect

Offset twills are obtained without reversing the twill direction In balanced twills, for instance, the risers of the first thread of a group are usually, but not necessarily, brought opposite the sinkers of the last thread of the preceding group An illustration of this type of twill is shown in the design 11 (Fig 1) They produce very attractive effects in fine worsteds and can be enhanced with color

paper first and other weaves filled in to serve the purpose. Into this grouping belong the famous tricotine, gabardine, and similar weaves, shown in Fig 1 by designs 6 and 8 They are very characteristic of fine worsted ladies' suitings, producing single and double twill lines that actually rise from the surface and stand erect in fine-yarn worsteds For this reason they are very popular and practically in constant demand A typical fancy twill is shown in Fig. 1 in design 10 These combination weaves can be carried to such dimensions that Jacquard looms are required to weave them In general, all such weaves for practical purposes are, wherever possible, drafted down to less than twenty harnesses

The twills as a group constitute the most important class of weaves for all types of woolen and worsted suitings and coatings and offer a great field for the designer to draw from continually in creating new patterns, designs, and effects By the use of these weaves, with the aid of color and all types of yarns, there are unlimited possibilities for application However, a designer is forced to keep his draft and weaves in simple and easily followed form, so that matters are not unnecessarily complicated in the drawing-in department and the weave room

The Satin Weave

This is the third of three main classes of weaves, namely plain, twill, and satin The object of the satin weave is to get away from the distinct diagonal of the twill and to produce a patternless, smooth, lustrous surface in the fabric The satin weave is extensively used in venetians, broadcloths, doeskins, meltons, and kerseys Satin weaves are usually constructed from a twill weave, but the interweaving of the two sets of yarns does not follow consecutively but at definite calculated intervals

Satin weaves are classified into two groups those in which the warp predominates on the face, called *warp flush sateens,* and those in which the filling predominates on the face, known as *filling flush sateens* The word *satin* originated in the silk trade, where the satin fabric is made with a satin weave The word *sateen* is more of a cotton term, employed to designate any fabric in which the filling predominates on the surface of the goods In the woolen and worsted trade the words *satin* and *sateen* are used interchangeably and promiscuously to mean the weave rather than any particular fabric as is the case in the silk and cotton trade The word *satinet,* however, was first used to designate a union cloth in which

the face shows only woolen filling, the cotton warp being covered entirely.

The principle involved in the construction of satin weaves is to determine the order of progression for the so called "stitchers" or points of interlacement between warp and filling. To obtain the combination from which to design a satin is to take any number of harnesses required of the original twill weave on which it can be woven and divide it into two parts. *These must not be equal, nor must one be the multiple of the other, nor should they be divisible by a third number.* For instance, the number 5 is divisible into 2 and 3. Beginning with thread 1 and progressing two warps threads to the right at each pick, the warp threads are stitched (bound) in the following order 1, 3, 5, 2, 4. That is, the first warp thread is stitched on the first pick, the third warp on the second pick, the fifth warp on the third pick, the second warp on the fourth pick, and the fourth warp on the fifth pick. Hence, it can be seen that each warp end is interlaced *with one pick only* and vice versa and that a scattered order of this interlacement is used so that no twill is formed at all, although a twill weave of 1 up and 4 down is used. This constitutes a filling flush and by a complete reversal a warp flush satin can be created.

The simplest satin weave, although not strictly a satin but a broken twill, is that made on four harnesses. It is shown in filling and warp effect in designs 13 and 14, respectively, of Fig. 1. The order of interlacing warp with filling is 1, 2, 4, 3. This is generally termed a "crowfoot" weave and is quite effectively used in stitching of double cloths and in broadcloths of all types. The twill line is well broken and with the proper yarn will produce a smooth, lustrous surface.

A more or less pronounced twill effect will be encountered in many of the satin weaves, particularly in the even-numbered harnesses such as six, eight, ten, or twelve harnesses or shafts, where no regular order of progression is possible. For instance, in a six-harness satin the only "move" numbers available are 2 and 4 (1 is not used), in the eight-harness satin 3 and 5 are available, in the ten-harness satin 7 and 3, and in the twelve-harness satin only 7 and 5 are available, and so on. The uneven-number harness satins produce the best effects, because a choice in progression exists, one of

which will suit very well, whereas some will show an undesirable twill line This rule applies mostly to uneven-number harness satins

Table 2 gives the order of stitching satin weaves on various harnesses, which have been found satisfactory in woolen and worsted work

TABLE 2

SATIN STITCHING ORDER

Harnesses	*Sequence of stitches*
5	1, 3, 5, 2, 4
6	1, 3, 5, 2, 6, 4
7	1, 3, 5, 7, 2, 4, 6
8	1, 4, 7, 2, 5, 8, 3, 6
9	1, 3, 5, 7, 9, 2, 4, 6, 8
10	1, 4, 7, 10, 3, 6, 9, 2, 5, 8
11	1, 5, 9, 2, 6, 10, 3, 7, 11, 4, 8
12	1, 8, 3, 10, 5, 12, 7, 2, 9, 4, 11, 6.
13	1, 6, 11, 3, 8, 13, 5, 10, 2, 7, 12, 4, 9
14	1, 6, 11, 2, 7, 12, 3, 8, 13, 4, 9, 14, 5, 10
15	1, 5, 9, 13, 2, 6, 10, 14, 3, 7, 11, 15, 4, 8, 12
16	1, 4, 7, 10, 13, 16, 3, 6, 9, 12, 15, 2, 5, 8, 11, 14

This table eliminates a lot of experiments and will serve as a guide in selecting the best progression for any satin weave between five and sixteen harnesses, which are most commonly in use

For the "warp effect" satins a closer set, or, in other words, more warp yarns per inch are used, whereas the reverse is true in "filling flush" satins If the weave is too loose, the result will be a spongy fabric of poor appearance, lacking handle and durability On the other hand, if the construction of the cloth is too tight it will be difficult to weave and get the required picks into the cloth and a "ribby" cloth will generally result Hence, a happy medium must be found and the filling shrinkage of the cloth carefully watched

Another factor is the use of the satin weave in stripes of all kinds Here it is sometimes necessary to crowd the ends in the reed at the stripe to accomplish desired density of weave formation Checks can also be made by using one harness for the crowding of the picks, if necessary This is done to some extent in ladies fancy worsted dress goods The satin weave can also be employed in colored yarn goods, where the warp is of one color and the filling of another.

One or the other can be brought to the face independent of the other, and without the other showing through if the yarn is reeded close enough.

Owing to the minimum amount of interlacing in these weaves, the strength of the cloth is not as good as with the plain weave, hence precautions must be taken if strength, slippage, and durability in satin weave fabrics become factors.

An important use of satin weaves is in double, triple, double-plain, and broché fabrics, where these weaves are employed in stitching the layers of cloth together or reversing the back with the face alternately, also in figured satins, where the warp and filling satins are alternated to produce patterns, figures, and motifs in regular or irregular order. There are also irregular satins and double-stitched satins, which, however, find less use in the woolen and worsted trade Color effects can be worked very well with satin weaves also

Of course, it will be realized that satin weaves can also be used in combination with other elementary weaves to form a variety of stripes, checks, overplaids, and color effects which defy the imagination

The Crepe Weaves

From time to time crepe fabrics are very much in demand and the crepe weaves find important applications These weaves distinguish themselves by giving the cloth a mixed or uniformly mottled surface. The more uniform this mixed or crepy effect is the better the crepe is considered They are of greatest importance in fine piece-dyed worsteds, where the clear finish preserves this beautiful, pebbly surface The important points to be observed in the construction of these weaves is the absolute absence of stripe and twill effects and to have each float approximately the same length No general rule can be given as each weave is peculiar in itself They are generally derived from plain or satin weaves, by transposition or rearrangement of two weaves or by drafting one weave over another and so forth One of the most common crepe weaves, as an illustration of this group, is shown in Fig 1 in design 16 Note the over-all mixed effect, where no float of greater than two picks or ends exists This particular weave is known as a "sand crepe" It repeats on sixteen ends by sixteen picks and requires sixteen harnesses

Crepe weaves exist in many varieties and are quite a study by themselves. It is one field where the designer can allow his skill and

originality to have full sway These weaves require not only imagination for the conception of new cloths, but also skill in drafting and the ability to determine what the weave will do in various types of goods

The Bedford and Other Corded Weaves

In order to obtain raised stripes or corrugated effects in either warp and filling direction, corded weaves are employed They are extensively used in worsted fabrics to produce Bedford cords, brochés, and over-all raised or matelassé effects in dress goods. The warp cords are usually developed by letting one pick float on the back under 4, 8, or 16 warp threads, then raising it above one or two (rarely more than two) ends, while the next pick interlaces the warp with a plain, twill or other suitable weave If a woolen cloth is woven in this manner and well fulled, the cord is made more prominent, because the floating picks shrink more readily, while the woven-in picks shrink less easily

A typical example of a warp cord, more commonly known here as a "Bedford cord," is shown in design 17 Note that the cords are warp-ways, consist of the same number of warp ends, namely six ends cord and 2 ends plain, alternating every two cords The design requires at least six harnesses to weave

Corded stripes can be woven without recess threads by making each pick float alternately on the back and interlace with the warp of the raised cord In one stripe it floats on the back and in the next stripe it is woven in The order is reversed on the next pick Very prominent corded patterns can be attained in this manner

To carry this corded effect a step further, "stuffing threads" can be introduced in between the face warp and the floating filling picks These yarns do not appear on the face at all and serve primarily to round or raise the corded effect on the face as well as to add weight if desired The yarns used are usually of inferior quality stock as they have no strain to bear To increase the durability of a corded fabric, the "stuffing threads" can be interlaced with the floating back picks, usually with a plain weave

In a similar manner cross cords or corded checks can be produced by letting every second or third warp thread float on the back for four, six, eight, or ten picks, while the other warp threads are woven with a plain, twill, or other weave Figured and diagonal patterns can also be produced with this weave A considerable quantity of these cloths are going into the better class of automobiles for upholstery purposes

Backed and Double Cloths

The backing of woolen and worsted cloths for the purpose of gaining weight of fabric as well as to create greater thickness is extensively practiced in the wool trade for "French backs" in suitings and the cheaper grades of boys' and men's trousering It is also used in decorative fabrics to produce small and indistinct figures, dots, plaids, etc. in single cloths, when they cannot be produced otherwise and without one showing through the other

Single cloths are considered to be those woven with one set of warp and filling yarns, even though they may differ in stock, twist, types of yarns, and weaves. The various effects produced vary principally through changes in drawing in drafts or in the sley or pickage While fairly heavy cloths can be made in this manner, fabrics with a worsted face and woolen or figured back require extra warp or filling threads

For these reasons a fabric can be backed in three possible ways *First,* by using one set of warp yarns and two sets of filling picks producing what is known as "filling-backed cloth," one filling for the face and one for the back side *Second,* by using two sets of warp yarns and one filling yarn only, producing what is known as a "warp-backed cloth" One set of warp yarns is for the face and one for the back side *Third,* by having two distinct sets of warp and filling yarns woven to make two different fabrics which are bound together at the edges only or at regular intervals so as to make one compact fabric This is technically known as a "double cloth."

Sometimes one fabric is superior to the other in quality of stock or one may wish to produce a plaid-back and the face of solid color as in overcoatings One fabric acts as a lining to the other Still further, it may be necessary for the face of the fabric to be rough or napped and the back smooth, and so on with unlimited variety of purpose The designing of such fabrics requires much skill and experience in order to produce workable weaves and color combinations A special system of designating the weaves and colors on design paper is necessary, which will be explained later.

Filling-backed cloths Filling-backed cloths are generally of a cheap, low, or medium grade They are produced when the backing filling is of a shoddy or a low grade of virgin wool It permits of a closely-set woolen or preferably worsted warp and a heavy woolen filling for the back and a worsted filling for the face. The filling

backing scheme has two distinct disadvantages which must be guarded against (1) the back filling has to be bound into the face in a thoroughly satisfactory manner, so as not to disturb the face, (2) owing to the use of an extra filling the production of stripes on the back is impossible, rendering this system unsuitable for fabrics requiring stripe or plaid effects, such as trousering and coatings

Filling-backed fabrics can be divided into distinct classes according to the sequence with which the face and back fillings are inserted, namely the "1 and 1" method, meaning one pick of face yarn follows one pick of back yarn. The second method is the "2 and 1" system, requiring two picks of face to follow one pick of back Other methods such as "3 and 1" or "2 and 2" are also used in American mills

The next important detail in connection with filling-backed cloths is the use of proper weaves and a system of "binding" the back filling to the face yarns In designing filling-backed cloths of any description the binding points, or places where the backing filling is interwoven with the face, are carefully predetermined and placed so as to prevent the backing yarn or stitch from showing in the face of the cloth

A very common method of backing a 2 up and 2 down twill fabric with an extra filling is shown in Fig 1 in design 19 Note that the face weave is 2 up and 2 down 45° twill and indicated by solid black squares The filling arrangement is one face pick followed by one back pick, which is the most satisfactory in this case Note also that the face warp is raised above the back filling, indicated by black crosses (X) except where the back filling stitches into the face warp, which is indicated by circles (O)

The latter are known as binding or stitching points or "sinkers" It is to be noted that the back-filling rises above *but one* warp thread at a time, also that the stitching of the back filling is distributed uniformly over all the warp threads Care must be taken that each thread gets the same amount of filling interlacing, otherwise those threads which are subjected to more frequent interlacing will have an increased take-up in weaving, causing them to become tight and break and result in a streaky cloth

The stitching points must occur in regular order, usually satin-order, wherever possible To get perfect binding in filling-backed cloths the "sinkers" on the back side should come between a "sinker" of the face picks on either side Stated differently, the stitches for the back filling should come where the pit will be covered by the adjacent face filling threads That is the secret of good binding.

Another important use of filling-backed cloths is in the cotton warp, worsted or woolen face, and woolen back type of fabrics such as friezes In friezes the chief object is to hide the cotton warp and to present a perfect, smooth, woolen or worsted surface Usually, ideal weaves and binding points can be secured in this class of goods When a cloth in which the warp predominates on the face, is woven back-filled, the latter must float at least twice as far as the face filling and be so interlaced that the stitches come on every twill line It is not always possible to have the stitching warp yarn below the face thread both before and after the back pick

Two back picks can be inserted between each face pick In that case one back pick passes below the other and floats twice as far A familiarity with the construction of back-filling fabrics and weaves is absolutely necessary before any dissection of such cloths is undertaken, because they are generally well fulled When it is impossible to stitch the back picks regularly, the "sinkers" are arranged to conform to the face weave

Warp-backed cloths These weaves are extensively used in worsted trousering and boys' and men's wear, where a close-set warp is employed They are less extensively used in heavy woolen fabrics, as it becomes difficult to form a good shed in weaving They can be used on medium-weight woolen fabrics, such as kerseys, hairlines, etc Warp-backed fabrics usually require a greater number of harnesses than filling-backed fabrics On the other hand, the addition of an extra warp to a single fabric allows the production of a better class of fabric than if extra filling is employed for the same purpose There is another advantage to be gained by using an extra warp on each side of the fabric an entirely different pattern can be produced

Two methods of arranging or dressing the warp are in use, the most common being the "1 and 1 method," i e , one face thread to each back thread The next method is the "2 and 1" having two face threads to each back yarn The seven most important points to consider in the design of these cloths are

1 The binding weave should be a satin or broken twill, avoiding as much as possible a regular twill

2 The fulling tendency of face and back yarns should be about the same, otherwise "cockling" will set in

3 When using the "1 and 1" arrangement, the face and back yarns should be approximately the same yarn size In the "2 and 1" method the back yarn should be twice the diameter of the face yarn

4 The binding points of warp-backed fabrics should be placed between risers of the face weave.

5 Two warp beams are desirable, if the face and back yarns are of a varying nature, such as worsted face warp and cotton or woolen back yarn, especially so if the "2 and 1" method is used and where the yarns used do not correspond as stated in paragraph 3

6 Every back thread should be bound on the average of once in every eight picks, according to the type of fabric

7 Warp-backed fabrics are drawn with face threads on front harnesses and back threads on rear harnesses

A typical example of a common warp-backed fabric is shown in Fig 1 in design 20 This fabric employs a 2 up and 2 down 45° twill face weave and a perfect binding indicated by crosses (X) The warp arrangement is one face and one back Note that the stitches are between two risers of the face warp and uniformly distributed

Trouserings and suitings constitute the bulk of the production of warp-backed fabrics and are woven with twills, herringbones, cut diamonds, and combinations of fancy twills, rib weaves, and whipcords. Warp backs are generally referred to in the trade as "French backs" In order to produce additional weight in worsted fabrics it sometimes becomes necessary to introduce "stuffing picks" between the face and back warp in the center of the fabric The usual order in such cases is two regular picks and one "stuffing" pick.

Double cloths The third class of backed cloths is the double cloth, which consists of two separate and distinct fabrics, face and back, employing two warps and two fillings, for varying purposes such as:

1. Tubular fabrics, such as roller felts, where the face and back fabrics are joined only at both sides, forming a tube or circular fabric.

2 To produce a thick fabric of uniform density, and principally to get warmth when the addition of a back filling would be insufficient

3 For the production of fabrics, the two sides of which shall be different, such as plaid backs, meltons, and coatings

4 To reduce the cost of a fabric by employing a good wool stock for the face fabric and a poor or cheap shoddy for the back

5. To increase the weight of the fabric without using extremely heavy yarns and open sleys, where the two fabrics are stitched together and appear as one distinct fabric

A double cloth is merely a combination of filling and warp-backed fabrics and the principles employed in its construction are similar

to those of the backed cloths just described The advantages of backed fabrics are retained whereas the disadvantages are overcome to a great extent The two fabrics may be identical in appearance and makeup, or one may be a coarse fabric and the other a fine one with the weaves or color arrangements differing radically without interfering with one another While in tubular felts they are stitched at both ends only, the more common procedure is to stitch the two textures carefully and regularly together by interlacing the threads of one fabric with those of the other during the weaving process They are extensively employed in the manufacture of kerseys, meltons, ulsters, montagnacs, felts, krimmers, chinchillas, and other uniform and coating fabrics They are not used on all-worsted fabrics generally

The designs and selection of weaves for such fabrics are made on design paper just as with single cloths, but the threads and picks on the design paper are divided into two separate groups, one for the face ends and picks and the other for the back threads and picks They can be marked separately or shaded to distinguish one from the other The grouping of the face and back ends and picks can be "1 and 1," meaning one face end is followed by one back end, in that case the face and back yarns are about the same size The "1 and 1" method permits the production of a fine fabric both face and back, the difference, if any, being in the pattern, weave, or finish given The "2 and 1" method is also used, whenever the back yarns are twice the diameter of the face yarns The latter allows a wider ange for variations in texture and counts of yarns or in the effects produced The combinations used in this method of designing double cloths are practically unlimited In the United States the better grades are produced by the 1 and 1 method and the "2 and 1" is employed for overcoatings and felts Whatever system is adopted it is customary to start the designs with one thread of face

The face weave is then filled in on the face threads and picks and the back weave on the back ends and picks The binding of the two cloths is then carried out by two prevailing methods

1 *Back-to-face method* or raising the back warp above the face filling

2 *Face-to-back method* or lowering the face warp below the back filling

In the first method the back warp thread must be lifted between two risers of the face and next to one or between two risers of the back weave The binding of the cloths by the second method requires that a face thread be lowered between two "sinkers" of the

face weave and next to one or between two "sinkers" of the back weave

In order to make this perfectly clear, a practical example is given in Fig 1, design 21, which represents the design of a typical double cloth as used in the American woolen and worsted trade The face and back weaves are a 2 up and 2 down 45° twill, filled in with solid squares for the face, and with crosses (X) for the back fabric Black dashes (—) represent face threads lifted over the back picks Binders or stitchers are indicated by circles (O) The "1 and 1" grouping of face and back threads is used for both warp and filling and the face-to-back method (number 2) of binding Note the fine distribution of the binders throughout the repeat of the weave The design requires eight harnesses for the face weave and four for the back weave, making a minimum of twelve harnesses

The simplest double weave is the double-plain, employed a great deal in women's novelty worsted dress goods with colors Fine checked patterns can be produced and it is known as a "reversible" weave which is often used in blankets and decorative cloths

The method of stitching has a great influence on the appearance and handle of a double cloth Of the two methods mentioned, the back-to-face is probably the most preferred, since the back warp is usually finer than the back filling, and hence covered better by the face threads when raised to stitch the fabric Stitching from face to back brings the back filling to the face

The designing of these double cloths of course becomes far more complicated when the weaves of face and back are different, and even more so when figures or color patterns are employed Care must be taken not to disarrange the color pattern and weave of the face in particular Also, when long filling flushes or floats are used, as in bolivia, chinchilla, and persian lambs, which are to be cut, raised, or napped apart, care must be taken in the reeding of these warps so that no gaps or openings result where stitchers or binders are used

Occasionally "stuffing" threads are introduced in these double cloths when the weight or thickness required cannot be obtained otherwise These stuffing threads may be warp or filling and lie between face and back They do not come to the surface at all and can be of any color or stock They also serve to increase the prominence of stripes and figured effects such as in piqué and matelassé In plaid backs the stitchers are from face to back to prevent different colored back threads from showing on the face The back weave is often plain when the cloth is made with a worsted face and woolen back

In fabrics in which there is a tendency for the binders to show, hard twisted cotton yarns are also employed They bury much better in the face-to-back or back-to-face method of stitching A divided drawing-in draft is the best, that is, the face and back warp come on separate shafts A straight draft usually requires more harnesses

The reeding on the "1 and 1" method should be four, six, or eight ends per dent, on the "2 and 1" method it should be three per dent (1 face, 1 back, 1 face) and six, nine, or twelve per dent, whereas in the "3 and 1" method four threads per dent (i e 1 face, 1 back, 2 face) are best

Montagnacs, Chinchillas, and Felts

There are a number of cloths which are made with extra filling of a loopy, bouclé, or krimmer novelty yarn These fabrics can be made in single cloths, and bolivias, bouclé, and tree barks are examples of this kind of extra filling fabric They can be made in heavier weights, however, of which montagnacs and chinchillas are examples In Fig 1, design 22, one of the common chinchilla weaves is illustrated It can be noted from the design that the face weave is a pile weave, the heavy filling binding-in for four ends and floating over eight ends in all instances and irregularly scattered in one repeat

The back weave is a four-harness "crowfoot" weave shown in Fig 1 in design 13 The grouping of the face and back warp and filling yarns is done by the "1 and 1" method The binding is in satin order and the method is back-to-face (1)) Face warp and filling is indicated by solid squares, the back weave by crosses (X), and the binders by circles (O)

Krimmers, montagnacs, and Eskimo overcoating are created in a similar fashion, generally in double and triple-cloths to get weight and density as well as warmth The loose floating face filling yarns are napped apart and later raised, curled, or rolled on special machinery in finishing The curly, looped bouclé fillings are steamed and allowed to rise from the face, producing fabrics of excellent character which are often mistaken for furs Imitation pile fabrics are created in this manner Much skill and experience is required of the designer and finisher in their manufacture. Cotton warps are also employed here and, for filling, mohair, alpaca, and luster wools are used Ringlets, clusters, and almost erect piles can be produced on the face through skillful manipulation of weave, stock, and finish They represent the ultimate in woolen fabric manufacture

Triple Cloths

Triple cloths are fabrics made with three distinct sets of warp and filling yarns and constructed in a manner similar to double cloths Drying, roller, piano, and mechanical felts are made in this way The three different fabrics are termed face, center, and back, and are tied together at certain intervals bringing about a completely firm and durable fabric of considerable thickness and hardness, or softness, as required By this method greater weight combined with equal fineness of appearance can be obtained Moreover, in double-cloth constructions it is sometimes necessary to resort to excessive shrinking in order to get the desired finished weight, which is apt to impair materially their elasticity and desirable handle Therefore, the triple principle of construction makes it possible to increase the weight without having recourse to abnormal shrinkage Such construction incidentally allows for brighter colored linings on back with the ever present danger associated with all double cloths, of these colorings penetrating through to the face, eliminated The stitching can be effected in the following ways:

1 Back to center and center to face
2 Face to center and center to back
3 Back to center and face to center
4 Center to face and center to back

An example of a triple cloth weave using the 2 by 2 twill for face, center, and back is shown in design 23, Fig 1 The method of stitching employed here is stitching center to face and center to back (number 4) The face weave is indicated by solid squares, the center weave by crosses, the back weave by Vs Diagonal lines running from right to left are placed where the center ends are raised over the back picks, and also where the face ends are raised over the back and center picks The dots indicate where the center is tied or stitched to the face and the circles where the center is tied to the back All marks with the exception of the circles represent warp up

By interchanging the back and center cloths in prearranged order, lining effects of a distinctly novel character may be obtained In this case, however, it is necessary that the weave be constructed on twenty-four harnesses, with the spot or interchanging portion arranged in block check or guard check order For clothing purposes three-ply cloths are rarely used, but experimental fabrics up to eight-ply have been made These cloths are primarily for industrial and special uses

Plushes and Velvets

Fabrics made by this class of weaves differ from all other cloths so far described in that they consist of a base or ground fabric, and an extra set of threads known as the "pile" They are commonly referred to as "pile" fabrics The pile can occur in *loop form* or in the *cut state,* forming a fuzzy or hairy surface Plushes may be divided into two main classes, namely filling pile fabrics and warp pile fabrics The former are cloths in which the pile (looped or cut) is formed by the warp yarn, while in the latter the pile is formed by the filling. These two classes may again be subdivided into "cut" or "uncut," or cut and looped pile. The warp pile fabrics require looms with oscillating reeds or special velvet looms, in which the pile is created by rods over which the pile warp is woven and then drawn out and cut or left in the looped state (See also the discussion of velvet carpets in the chapter on carpets and rugs).

Filling plushes. Filling plush is the simplest form of all pile fabrics The cloth is formed by a series of filling threads floating on the surface The operation consists of weaving a ground or base fabric, plain or otherwise, and weaving in a filling floating loosely over the surface and bound into the ground fabric at certain regular intervals Much depends on the firmness of the ground cloth and the even distribution of the pile picks, where and how they are bound in, so as to prevent pulling out of the pile picks during the cutting operation The ground weave may be a plain weave, 2 and 2 twill, or a 2 and 1 twill. The pile filling float must consist of a long float covering from three to ten warp ends It is very common to construct filling plushes with three pile picks to one ground pick in order to obtain a dense pile

The floats are then cut after weaving by a skilled person, who places the cloth section-wise on a table and with the point of a sharp cutter, especially constructed for this purpose, runs under the floats and cuts them in rows following the weave at right angles or diagonally to the filling This is repeated until all the floats are cut. In certain fabrics the back of the cloth is painted with glue to make the fabric firm, and prevent slipping out of the cut pile while adjacent floats are being cut The fabric is then napped, brushed, beaten, and sheared to bring the pile to an erect and even position. If colored, the dyeing is done previous to cutting Mohair, rayon staple, and luster wool are commonly employed for the filling pile yarns and cotton or worsted yarns are commonly used for the ground

Warp plushes Warp plushes are made with a ground warp and a pile warp on separate beams and one filling ground yarn Warp pile fabrics are woven and cut on the loom by a special type of loom The pile warp is raised in the shed, a wire of the size to give the desired loop or height of pile is inserted into the shed, and then the pile is lowered and interlaced with the ground filling The loops formed by the pile warp and wire may be cut to form the common plush or may be left uncut to form terry effects or upholstery friezes If the loop is to be cut, the wire over which the pile warp passes is equipped at one end with a knife, which cuts the pile as it is withdrawn The ground weave may be either a plain weave, a warp rib weave "2 and 2," or any closely woven twill The pile warp is woven very loosely and has a large take-up One half of the pile warp is generally raised at one pick in order to distribute the pile regularly The pile must be woven into the ground fabric quite closely and here two methods are recognized: namely the V pile and the W pile The V pile interlaces only one ground pick, whereas the W pile interlaces three ground picks in succession Carpets are made in a similar manner

The warp plushes are generally woven double (face to face) with the pile woven between them The weaves used for this purpose are shown in designs 24 and 25 in Fig 1 The upper one show a design using two ground warp to two pile warp, weaving plain producing a V pile The lower shows a "2 and 1" arrangement of ground and pile respectively showing a W pile construction The latter is much preferred because of the greater firmness it creates in the pile surface, and greater resistance to being pulled out The ground weave is indicated by solidly filled in squares, whereas the pile weave is shown by crosses (X) Mohair, rayon staple, and luster wools are used for the pile, while mercerized cotton or jute are employed for the ground fabric to give strength

The filling plushes find considerable use in dress materials, trimmings, and opera cloakings, whereas the warp plushes find considerable use in railroad seats, motor car upholstery, and drapery materials The latter are generally more sturdy and heavier in weight and construction than the former

The weaves described in this chapter constitute the bulk of weaves and fabrics made in this country with the possible exception of the leno weave The latter consists of adjacent warp yarns whipping a half turn around each other and taking the filling pick between each The leno weave is rarely used except in double-width goods where it weaves the cutting line, or in carpets

Chapter 18

DYEING, BLEACHING, AND PRINTING

DYEING has l een practiced for thousands of years, and among the earliest peoples who dyed their garments were the Chinese and the American Indians The dyes that were available to the ancients were produced naturally by plants and animals There were two principal colors blue indigo, which originated from a plant, and red kermas, obtained from the dried bodies of an insect

Probably the most interesting documents on dyeing have been recovered in Egypt, the "Papyrus Graecus Homkensis," preserved at Upsala, Sweden, and the "Leyden Papyrus," preserved at Leyden, Belgium The former contains seventy recipes dealing with the cleaning, mordanting, and dyeing of wool, in which the following dyes are mentioned. alkanora (red), safflower (ye'low and red), kermas (red), madder (red), and woad (blue) The art of dyeing was well developed, following the same principles that underlie modern dyeing

The discovery of America added different dyewoods such as logwood, redwood, and fustic to the available dyes The most important of the dyewoods, and the only one still used on a large scale, is logwood The dye is extracted from the blood-red wood of the campeachy, a large tree which grows abundantly in the West Indies and Central American countries The dye is sold today in the form of logwood extract

In addition to dyewoods, the Spaniards found in Mexico an insect which produces cochineal, a beautiful scarlet with a tin mordant which has replaced the less attractive kermas red There is every indication that the more cultured inhabitants among the Indians of Middle America and South America used these colors to a great extent Garments and blankets found in the Inca graves in Peru and Chile, dating from before the Spanish Conquest, are examples of the various dyes used such as purple and indigo The Incas were able to apply these dyes on wool as well as on cotton

Modern Dyestuffs

The whole art and practice of dyeing was completely revolutionized in 1856 by the discovery of the artificial dye mauve, (from the French name of the violet-colored mallow flower) The discovery was made

accidentally by a young English chemistry student, William Henry Perkin.

When his discoveries were published, chemists all over the world began to manufacture and experiment with the new dye Factories were started all over Europe From this beginning, the manufacture of coal-tar dyes, and more recently their allied compounds, has become one of the most important and most profitable of all chemical industries

Since that time not a year has passed without several new dyes being put on the market by some of the great dye concerns Of late years, concentrated efforts have been made to standardize the dyeing procedure as well as the many fastness properties for each dye

Statistics on Dyes

The U S Tariff Commission report on synthetic organic chemicals for the year 1945 indicates that there are forty-four producers of dyes in the United States A production of 144,296,000 pounds at a unit value of 75 cents is shown as compared to 101,932,661 pounds at a unit value of 53 cents for 1935 The higher unit value is undoubtedly due to the increasing percentage of higher priced colors such as azoics and vat colors, and the trend toward higher concentrations that was accentuated during the war Azoics, not separately shown in 1935, represent 6 9 per cent of the total in 1945 Vat colors, excluding indigo, increased from 19 1 in 1935 to 36 1 per cent of the total value in 1945

The American industry has continued to duplicate foreign colors and to introduce new colors The *Yearbook* of the American Association of Textile Chemists and Colorists now lists 359 prototypes, indicating that there are at least this many instances in which American producers have duplicated foreign colors which did not have numbers in the old *Color Index* In addition to this, 3 6 per cent of the value in 1945 was in unclassified dyes as compared to 1 3 per cent in 1935

Imports in 1945 were 1,124,191 pounds at a unit value of $1.45 as compared to a much higher figure of 3,638,177 pounds in 1935 at a unit value of $1.51 Whereas 50 per cent of the volume of imports in 1935 were from Switzerland and 49 per cent from Germany, in 1945 89 per cent of the imports were from Switzerland and 11 per cent from England

Exports in 1945 were 20,849,255 pounds with a value of $18,647,131 as compared to 19,630,924 pounds in 1935 with a value of $6,873,404. Here also, higher unit value may be attributed to the shipment of more expensive colors and stronger types Major markets for United States

dye producers were India, Latin America, and Canada, which took 34 8, 29 4, and 26 7 per cent, respectively, of the total

Dyes are derived from the coal tar crudes, benzene, toluene, xylene, and naphthalene, through intermediate steps that, in some cases, are also used in the production of chemicals for other industries such as rubber and plastics Phthalic anhydride, for example, which is the starting point for the anthraquinone vat dyes and for the acid alizarine dyes, increased from a production of 23,421,558 pounds in 1935 to 125,033,000 pounds in 1945, primarily due to the demands for this raw material for the plastic and protective coatings industries Similarly, aniline oil increased from a production of 32,572,809 pounds in 1935 to 87,195,000 pounds in 1945, primarily because of its extensive use in chemicals for both natural and synthetic rubber

Classification of Dyes

The dyestuff concerns in the United States are manufacturing in excess of 2,000 dyes for the textile, paper, leather, plastic, and other industries Dyes are exceedingly complicated chemical compounds requiring many steps in their production that must be closely controlled by qualified technicians The percentages in dollar value of all dyes marketed in 1945, by class of application, is given in Table 1

TABLE 1 DYES PRODUCED IN THE UNITED STATES, 1945 IN PERCENTAGE OF DOLLAR VALUE

Class	*Per cent*
Acetate rayon colors	3 5
Acid colors	13 3
Azoic colors	6 9
Basic colors	6 2
Direct colors	17 0
Lake and spirit-soluble colors	2 7
Mordant and chrome colors	4 7
Sulfur colors	4 1
Vat colors	38 0
All other coal-tar dyes	3 6
TOTAL	100 0

All the chrome or mordant colors and a substantial portion of the acid dyes and small but increasing amounts of vat and azoic dyes are now being used by the wool dyer. Acid dyes are used, in addition, on paper and leather, vat dyes on cotton and rayon, and the sulfur dyes are practically restricted to cellulose fibers

The large dye concerns furnish the trade with excellently made-up sample cards, showing actual dyed wool samples in the form of loose wool, yarn or small swatches, and the shade and strengths of the various dyes In addition some of them publish valuable wool manuals An outstanding one is the *Manual for the Dyeing of Wool and Mixtures of Wool with other Fibers* distributed by the General Dyestuff Corporation

Designation of Dyes

Trade names In these sample cards and manuals, the dyes are grouped according to the class of application In each class of dyes they are arranged according to the color and their relative shades beginning with yellow, orange, red, violet, blue, green, brown, and black For proper identification of a dye the manufacturer gives each dye a trade name The trade name usually bears a reference to the class, property, and color of the dye as "Acid Light Red G", or to its chemical composition as "Anthraquinone Blue B" or "Alizarine Yellow GG" In many cases it is simply an arbitrary name assigned by the manufacturer or his local agent

Letter designations The letter or letters following the name generally refer to the shade, for instance, B for blue, R for red, Y or G for yellow (German *Gelb*) For example, "methyl violet" is sold in brands running from 6B to 6R—that is, from a shade very close to blue, over purple, to a bright red-violet shade Sometimes the letter refers to a fastness property such as "Acid Green L Extra" where "L" indicates fastness to light In other instances the letter refers to its class, as "Wool Green S" (German *Sauer*) acid Very frequently the letter is merely a mark applied for purposes of identification, such letters are N and M

Abbreviations and percentages In addition to the letter designations there are such terms as *conc* and *extra conc*, which are abbreviations for the concentration of the dyes These terms were further broadened by the addition of a percentage figure such as 100 per cent or 125 per cent, meaning in this case that the 125 per cent dye is 25 per cent stronger in its color value than the 100 per cent During World War II most manufacturers increased their dye concentration in order to conserve packing material In buying dyes the concentration factor is one of the most important things to consider, because the same dye may be sold in various concentrations and the prices are based accordingly

Index numbers The index numbers commonly used for dyes were

established by *Rowe's Colour Index*, published in 1924 by the British Society of Dyers and Colourists This book is now being revised by the same British Society, collaborating with the American Association of Textile Chemists and Colorists It is expected that this revision will include all the commercially used dyes. As a result of a study of the general plan and policies to be followed, it was determined that the book should have three major functions: (1) to provide information on the method of application, the fastness properties, solubility, and the established usages of commercial dyes, (2) to catalogue such information as is available by chemical structure and components and to describe briefly the preparation of technical dyes, (3) to correlate the different commercial names of individual dyes

With these objectives in view, the second edition will be divided into three parts:

Part I Application information on all commercially homogeneous dyes and pigments in current use within groups appropriate to the most important usage Each usage group will be subdivided into hue groups

Part II The chemical structure of all dyes and pigments appearing in Part I that have a disclosed chemical constitution Also, brief data on method of preparation, reactions in substance, and solubilities and a summary of usage and hue descriptions

Part III A commercial names index, alphabetically arranged, of all dyes appearing in Parts I and II. This section will also be used for those commercial names that do not qualify for treatment in Parts I and II because of a lack of information

One of the main functions of the color index is to correlate the different commercial names of individual dyes For example, color index number 31 refers to the basic type, "amido naphthol red G," which is manufactured by the Cincinnati Chemical Works, Inc The same product is sold by eleven or more other producers each under another trade name By this numbering any dyer today is able to find for the most common wool dyes the various competitive products on the market

Theory of Dyeing

That the wool fiber has an affinity for almost all artificial dyes becomes apparent when a colored effect appears when wool is dipped into solutions of the dye in water or other solvents The affinity changes with the different chemical compositions of the dyes, and consequently the conditions also vary under which the union of the dyes with the wool fiber is best brought about

The mechanism of the process by which dyes become permanently fixed on textile fibers is not yet clear to chemists Different theories have been advanced to explain the process There is, on the one side, the chemical theory and, on the other the physical theory For wool dyeing, the chemical theory is most favored, because of the prevalent idea that the dyes undergo a chemical combination with the wool fiber. The chemical theory is strongly supported by the work of research workers in Germany, Russia, England, and in the United States by Arthur Smith and Milton Harris[1] Their work leaves little doubt that the reaction of wool with acid dyes is governed by chemical laws and consists of the neutralization of the basic groups in the fiber by the acidic groups of the dye molecules

The acid-combining capacity of wool has been found by several investigators to be about 0 80 millimole of acid per gram of wool The following diagram illustrates the reactions which take place in acid dyeing.

Wool protein basic groups + Sulfuric acid ⟶
Wool protein acid sulfate + Water

Wool protein acid sulfate + Sodium color acid ⟶
Wool protein color acid + Sodium sulfate

In order that goods may be dyed evenly, the dye should be deposited slowly and regularly on every part of the material This necessitates a movement of either the dye liquor or the goods. Either the liquor may be made to circulate, the goods being stationary or, vice versa, the goods may be moved through a stationary liquor Sometimes one method is used and sometimes the other, but all dyeing apparatus must have some provision for circulating the liquor, the goods or both A dye bath must also be provided with some means of heating the dye liquor. At times the bath is heated directly by means of a steam-jacket, steam-coil, hot-water system or by passing live steam into it, in other cases the liquor is heated externally and caused to circulate through the goods by means of a pump or a propeller

The water for wool dyeing must be of the same high purity as that used in wool scouring For the chrome-dyeing process water of zero hardness is preferred as some of the dyes are sensitive to lime salts In

[1] "Nature of the Acid Dyeing Process," *American Dyestuff Reporter,* Vol 26, 416, 1937

acid dyeings the hardness does not play such an important part, as most of the dyes are not sensitive to metals and the presence of strong acids further reduces the danger.

Wool-Dyeing Machinery[2]

Wool may be dyed in any stage of manufacture—as loose wool or stock, as slubbing or top, as yarn, or as piece goods The mechanical devices used in wool dyeing are built according to the state of the wool With a few exceptions, the dyeing is done in mechanical apparatus, because of considerable saving of time and labor over the old method of dyeing in open vessels and manipulating the material by hand In the construction of modern machinery special attention is given to the fact that the wool fiber must be preserved as much as possible, especially to retain its suppleness and soft handle The felting of loose material is prevented, which likewise guarantees smoother carding and spinning and a better yarn with fewer breaks The various kinds of apparatus on the market are built to attain these advantages in various ways First to be considered is the great number of dyeing apparatus for treating the loose and spun material.

No one type of apparatus may be used for all kinds of material with the same good result, as no apparatus is of such construction that it may be used for dyeing loose wool as well as hanks, packages, and cops To obtain good results in wool dyeing any excessive pressing of loose wool must be avoided—this fact is of special importance Pressing of yarns also is injurious and must be avoided, for this reason dyeing is frequently carried out with the yarns in several layers of moderate thickness Wound packages, such as tops or cheeses, however, may be pressed in the direction of their axis without impairing the wool fiber

Construction of Dye Apparatus

For good results in dyeing, the material of which the apparatus is built is of great importance Up to recent times metals in machinery for wool dyeing were generally avoided whenever possible Iron, in particular, is unsuitable for most wool colors as it strongly affects their tone The vat colors are an exception, and the circulation vats used for these dyes are made of iron Copper also has an unfavorable effect on some dyes and tends to cause stains Lead or hard lead should not be

[2] *The Dyeing of Wool in Mechanical Apparatus* Cassella, L & Co 1925

employed in apparatus in which chrome colors are handled For the pumps or propellers, phosphor-bronze has proven to be best, as it offers good resistance, especially to the acid bath

Because of these facts, wooden vessels formerly were given preference, pitch pine, well-seasoned and without knots, was found most suitable. A great drawback of the wooden vessels is the penetration of the color solutions into the wood, so that when dyeing different shades—particularly if dark shades are followed by light ones—a boiling-out of the apparatus became necessary previous to dyeing

Introduction of stainless-steel machinery One of the greatest forward steps was the change in the construction material of the dye kettles from wood to high-grade stainless steel Prior to 1930 stainless-steel machinery was entirely unknown When stainless-steel machinery was introduced in the early 1930's its cost was about three times as much as wooden machines However, this much higher initial cost did not prevent a few progressive manufacturers from modernizing their old equipment

The advantages of stainless steel—high resistance to corrosion and inertness to dyes and chemicals—are well known In addition, the ease of cleaning the kettles allows much greater flexibility During the change from wood to metal, many concerns shunned the high cost of stainless steel and tried other metals only to experience even higher expenses arising from the unfavorable effect of these metals on some of the dyes and the lower corrosion resistance, resulting in shorter kettle life Today, there is hardly a woolen and worsted dyehouse that does not possess at least a few stainless-steel kettles The older equipment is being rapidly replaced, especially since the price of stainless-steel kettles has decreased considerably. In some instances the stainless-steel is even cheaper than wooden kettles There are two grades of stainless steel which have proven satisfactory, namely, the 19-9 and 18-8 SMo, the latter being the better grade The change in economy demanded that the increased costs be met by increased production Not only was this increased production accomplished by building larger machines but also by introducing time and temperature controls As these devices replace to a large extent such manual labor as the opening and closing of valves and the timing of operations the saving in labor costs is considerable Carefully controlled temperatures go hand in hand with steam savings An additional feature of these controls is their invaluable contribution to preserving the quality of the dyed wool Realizing the importance of these controls the progressive machine builders today incorporate control panels in the design of their equipment

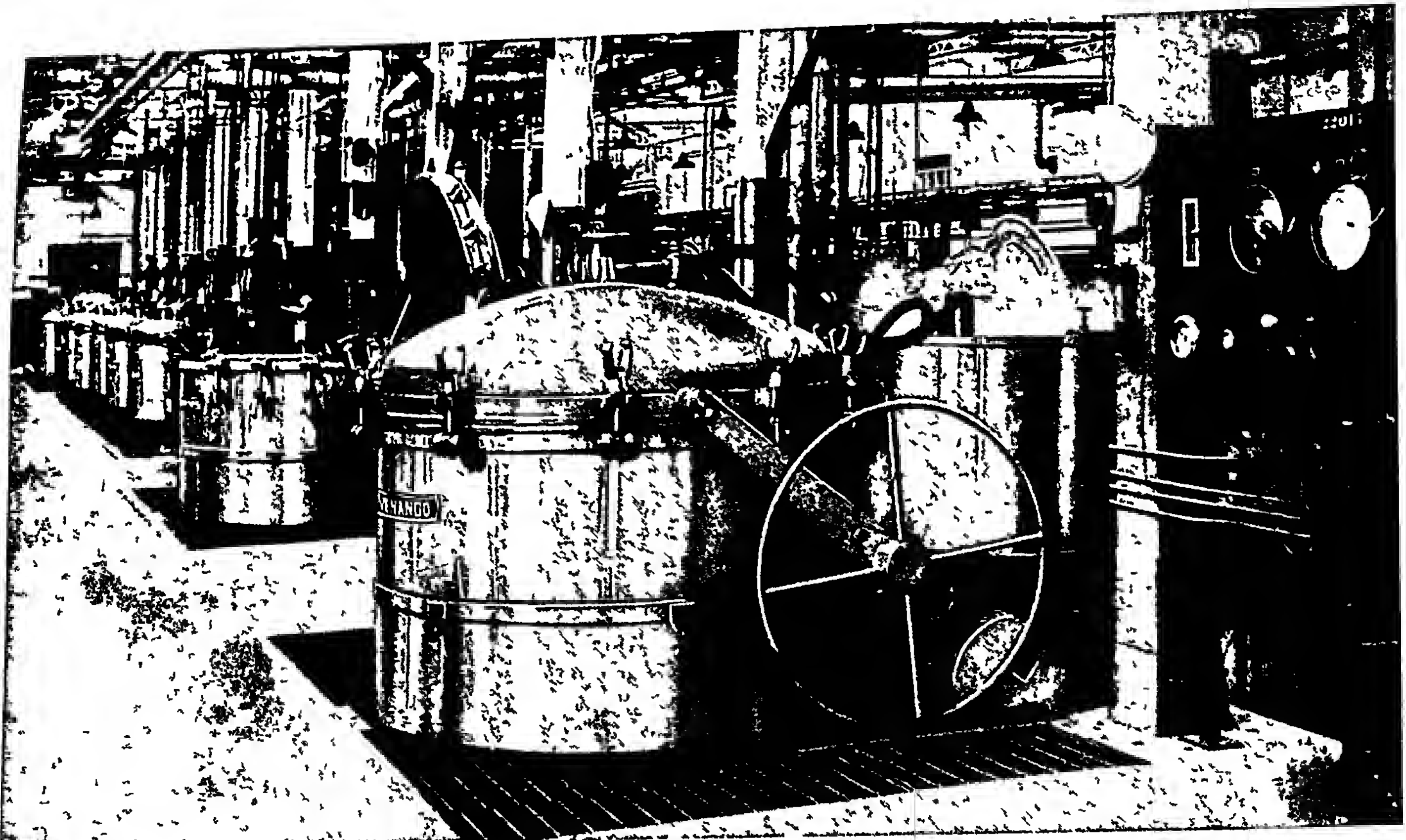


Fig 1 Venango raw-stock and package-dyeing installation
(*Courtesy Forstmann Woolen Company*)

Raw-Stock-Dyeing Machinery

Apart from the old-fashioned way of dyeing, using open wooden tubs and stirring by means of long wooden poles, the loose wool stock is now dyed in two different types of machines. (1) the open type, and the (2) closed or pressure type In both types the stock is stationary and the dye liquor is forced through the mass by means of a pump or by a propeller.

Up to the early 1920's most of the dye vats and kettles were of the open type, which meant that the dye house was filled with a dense fog on cold days Today, most of these machines are enclosed, particularly the ones used for stock and yarn dyeing This again means considerable savings in steam consumption and at the same time is one of the best and simplest remedies for curing a fogged-up dyehouse.

Open stock-dyeing machine The wool to be dyed according to the open system is packed in one or several layers and is prevented from boiling over by a perforated cover placed (without exerting too much pressure) on top The circulation of the liquor is brought about by pumps or propellers Figure 1 and Figure 2 illustrate the two systems The use of a pump or a propeller permits an alternating circulation of the dye liquor This reverse action is necessary in the open-type kettle to free the wool from air Air bubbles remaining in the material cause undyed spots and, in most instances, by proper alternating of the circulation the white dots may be avoided The alternating circulation is beneficial only for the wetting out Once actual dyeing has started it is much better for the preservation of the strength of the wool to run the machine only one way, from the inside out

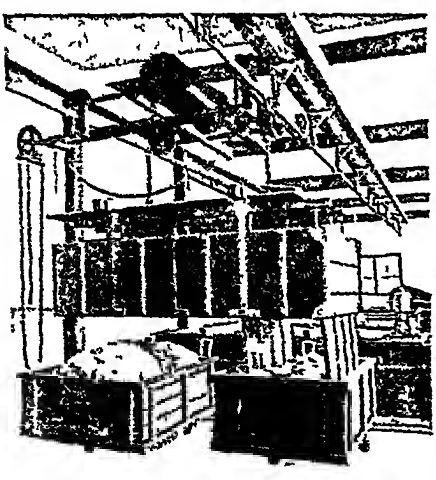


Fig 2 Unloading method of Hussong raw-stock-dyeing machine

When working with apparatus with the steam coil fixed inside, it is advisable to shut off steam while the liquor is penetrating the material from below upwards, since otherwise there would be danger of the lower layers becoming too deep a shade because of excessive heat and of the material suffering in consequence The installation of a separate heating chamber for heating the

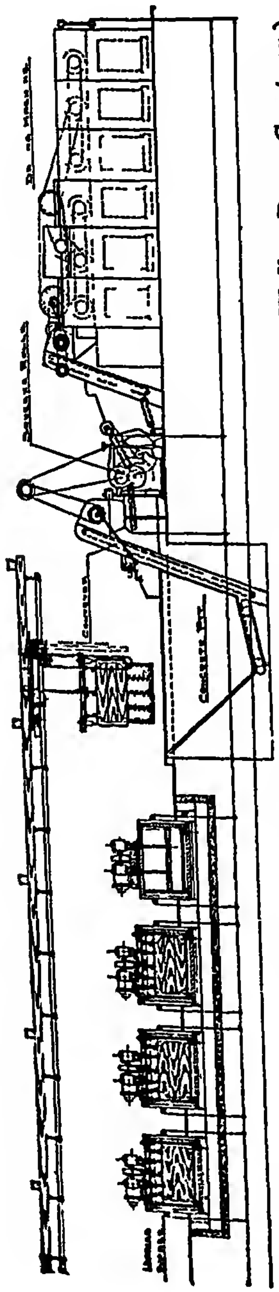


Fig 3 Stock-dyeing vats with unloading and drying equipment. (Courtesy Hussong-Walker-Davis Company)

liquor is for this reason more advantageous and builders of wool-dyeing machines quite generally pay due regard to this fact Dyeing in one layer is generally preferred when dyeing loose wool, since larger quantities may thus be dyed in one lot.

The best-known representative of the open machine is the Hussong machine This machine (Fig 2 and Fig 3) consists of a rectangular vat with two sections, the smaller section on one end of the box carries the circulating equipment, consisting of a motor that drives two propellers situated in the lower part of the box The wool is packed in a removable metal basket that rests on a protruding ledge inside the larger section in the machine To save steam the cages have tight-fitting covers

The procedure is as follows The cage is loaded away from the machine by manual labor, which has to be done very carefully to avoid uneven places which would allow the liquor to penetrate certain places more freely, causing uneven dyeing The loaded cage is then closed and, with the help of a hoist, transported into the dyeing chamber in which the dyeing liquor has been previously prepared The motor is started and the propellers force the dye liquor through the material in the cage The circulation is easily controlled by a switch for starting, stopping, and reversing The liquor is heated by perforated steam pipes running along the bottom of the dye chamber When an addition or a change of the bath is necessary, the cage can be elevated in two minutes The unloading of the cage after completion of the dyeing is done very rapidly by lifting the cage out of the machine and running it on the overhead track away from the machine The bottom of the cage is so constructed that it can easily be opened and

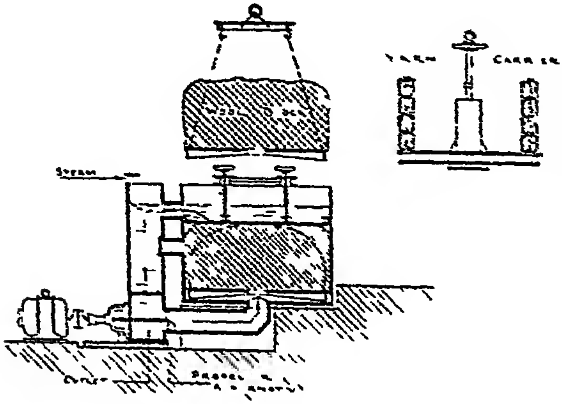


Fig 4 Obermaier stock-and yarn-dyeing machine. (*Courtesy Standard Fabricators, Inc*)

the stock emptied either in trucks or into a pit directly on to a conveyor belt, which delivers it automatically to squeeze rollers and later onto a continuous drying machine (Fig 3) The unloading time is less than five minutes after which the cage is available for a new lot The machines are built in seven different sizes, from 20 pounds up to 500 pounds wool capacity When used for rags, noils, or similar material the capacity increases

Another machine of the open type is the Obermaier (Fig. 4) The material is packed into a circular vat and rests on a perforated bottom. This bottom acts as a carrier and can be lifted out of the machine, after the dyeing process, with the help of the chains fastened to it By replacing this loose wool carrier with a yarn carrier the machine can be converted into a yarn-dyeing apparatus

Pressure stock-dyeing machine Representing this type of machine are the Franklin, the Riggs and Lombard, and the Venango. Figure 5 shows diagrammatically the general construction and the liquor flow of the pressure machines The Franklin and the Venango machines have the expansion tank separated from the main kettle whereas in the Riggs and Lombard machine the main kettle and expansion tank are one unit eliminating thereby all outside pipes, valves, and fittings except steam, water, and drainage connections

The expansion tank is used for feeding and dissolving the dyes and chemicals In loading and unloading the same principles are used as in the Obermaier open machine Depending on the type of carrier, the machines can be used for stock as well as yarn dyeing The pressure range is from 10 to 50 pounds per square inch The Franklin and the Venango machines are equipped with pumps, whereas the Riggs and Lombard machine uses a propeller to circulate the liquor The one-way circulation produces the best results in stock dyeing The pressure machine preserves the material being dyed better than the open machine,

resulting in yarns which are 5 to 10 per cent stronger Yarns spun from stock-dyed wools are generally from 15 to 30 per cent weaker than the same yarns spun from white wool, depending on the depth of shade and the dyeing procedure

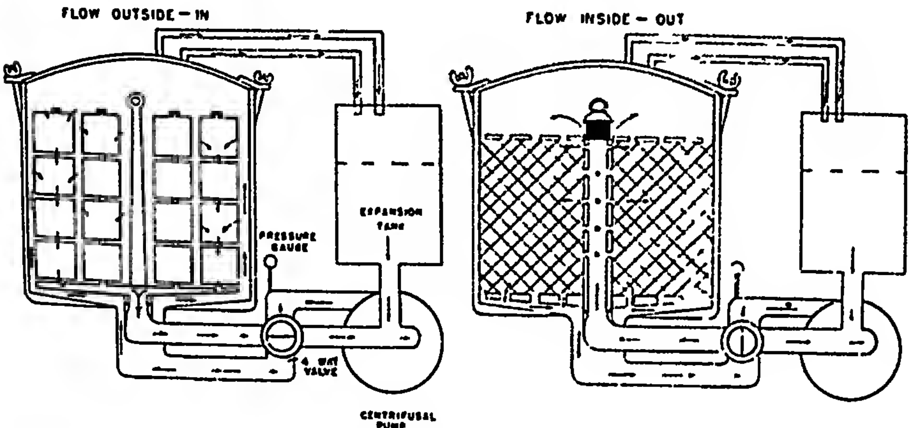


Fig 5 Liquor circulation in a pressure-type stock-yarn dyeing machine indicating flow of liquor through raw stock as well as yarn packages

Vat-dyeing apparatus For dyeing vat colors, the so-called circulation vats are used which are built on the same princple as the two systems just described Contrary to other wool-dyeing machines, they are generally built of iron, as iron resists the weak alkaline vat liquors best and does not adversely affect the vat colors themselves

These special vat-dyeing apparatus, like the open dye vats, are provided with an inner receptacle to hold the wool It may be closed with a perforated lid and lifted by means of a winch Connected with the apparatus is a pair of strong squeeze rollers, which provide for very thorough extracting of the dyed wool The circulation of the liquor is effected exclusively by pumps with reversible action The bottom part of the inner receptacle fits tightly against the outer dye vessel, its sides are solid and only the bottom and the removable lid are perforated, thus forcing the liquor to circulate through the material either from above down or in the opposite direction

Continuous process In the early 1920's the trend towards mechanization of the small batch machine was the light of progress Today mechanization has reached the point where dye houses are entering the era of continuous processing in dyeing, a natural development in this age of streamlining Probably the first fully continuous dyeing process for

wool stock was developed during World War II Its application was limited to indigo, which would mean low-temperature dyeing The process is based on the passing of the loose wool through a dye train approximately 200 feet long The machine (Fig 6) is more or less a duplicate of a raw-wool scouring train and consists of eight bowls interconnected by squeeze rollers and mobile aprons in which the wool is transported through the bowl liquor at a fixed rate of speed by the propelling motion of harrow forks It takes the wool forty-five minutes to travel from the first feeder of the machine to the outlet of the dryer The delivery is regulated so as to assure even feeding and to maintain a production of 550 pounds of dyed wool per hour

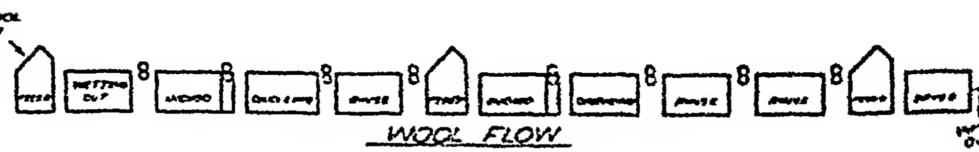


Fig 6 Diagram of indigo dye train.

Each bowl in the dye train performs a specific function The first bowl serves to wet out the scoured wool prior to its entrance into the dye vat. the second and the fifth bowls constitute the dye vats; the third and the sixth bowls act as the oxidation baths, and the fourth, seventh, and eighth bowls perform a rinsing operation Concerning dimensions and mechanical and structural operation, the two dye vats are larger and slightly different from the others Basically, the construction of all eight bowls is similar Each bowl is divided horizontally into two sections by a perforated iron plate that extends along its entire length, approximately 1 foot below the top rim of the bowl

Temperature equilibrium is maintained throughout operation by thermostatically controlled heating coils, also located in the segment of the bowls directly below the perforated plates. Regular steam inlets are incorporated in each bowl for adjusting the liquor temperature to the desired level in the shortest time when starting up with fresh liquors The squeeze rollers located at the extremity of each bowl direct the excess liquors into an overflow compartment, separate from the bowl proper From this overflow compartment the liquor may be pumped back as the beginning of each bowl, as in the case of the wetting out and the oxidizing and rinsing baths, or pumped to other points in the circulatory system, as in the case of the dye vats

The second and the fifth bowls constitute the dye bowls and entail special features, as shown in Fig. 7 They have a wooden ducker roller

A, located before the range of the harrow rake Across the entire width of the machine, the transverse blades of this roller immediately sweep the material below the liquor level To maintain this submerged position of the material the first four rows of the harrow forks are fitted with perforated metal immersion boxes *B*

Because of the consistency of the dye-bath liquor and the increased material ratio in this bowl, it has been found mandatory to disarrange the harrow rakes from their parallel position This new unparallel arrangement inverts the material during its passage through the bowl The harrow fork delivers the material to a more rapidly moving crab *C* The crab is comprised of several rows of metal prongs of ever-decreasing length that urge the material into the dry nip of the squeeze rollers D_1 and D_2 To alleviate the effects of pre-oxidation of the dye bath at this critical stage a partially submerged arrangement of the bottom roller is necessary This prevents cascading of the liquor

The squeeze rollers are in a compartment *E*, attached to the body of the bowl but separated by a plate *F*. This separation plate reaches up to the false bottom *G*, thereby eliminating the passing of contaminated liquor to the dye bowl proper, directly behind the submerged squeeze roller The top roller D_1 which is slightly larger in diameter, is lapped with hard rubber, while the bottom roller D_2 is constructed of iron The speed of rotation of the roller on the dye bowls is approximately twice as high as in the other bowls

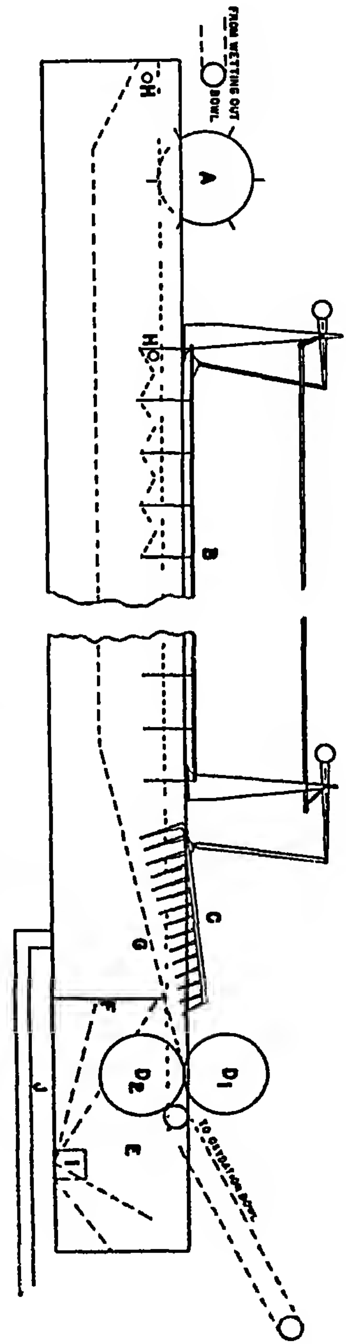


Fig 7 Construction detail of the continuous indigo dyebowl

The liquor is fed to the dye bowls at two points *H*, both being below the surface of the liquor One is located directly behind the ducker roller, whereas the other is approximately one-quarter of the distance to the squeeze rollers Circulation is maintained by the continuous drawing of squeeze liquor from the overflow compartment of the first dye bowl, straining it in the material trap *I*, and pumping it to the second dye bowl from where the same procedure of drawing, straining, and pumping delivers the liquor to the feed tank for replenishment and, thence, to the first dye bowl again A 4-inch equalizing line *J* between both dye bowls is conducive to a constant liquor level

Top- or Slub-Dyeing Machinery

In the days following World War I probably the largest percentage of top was still dyed (in the Klauder-Weldon machine) in the form of hanks mounted on revolving carriers that are fixed on dye wheels With half of the wheel in the dye liquor as it turns, the slubbing passes continually through the stationary dye liquor.

In this type of machine a certain amount of felting is unavoidable and this, coupled with the trouble of unwinding the tops and balling them again after dyeing, has called into existence numerous machines in which the tops are dyed as such Two main systems are in use In one, several balls are placed over perforated pipes, called spindles, which are enclosed within a cylindrical tank, the lid of which is securely tightened. The lower ends of the spindles are inserted into a perforated bottom The dye bath, made up in an auxiliary tank, is circulated by pumping it through the balls with enough pressure or suction to overcome the resistance of the wound top and to get a desired rate of flow The Franklin Process Company specialized in this type of machine The difficulties with this machine are in the loading, which, if not properly done, leads to uneven penetration

A similar but open machine is built by Riggs and Lombard It consists of a rectangular box, to the bottom of which is attached the desired number of perforated spindles At one end of the machine is located a vertical, motor-driven, centrifugal pump

During the dyeing operation the tops are compressed and held in place by the conventional cap and bar arrangement Unloading may be accomplished by means of a chain hoist fastened to the clamping bar, which in turn lifts all the tops in *one* operation with the aid of chains that are fastened to lifting plates under each column of tops

A new way of top dyeing was introduced by the Abbott Machine

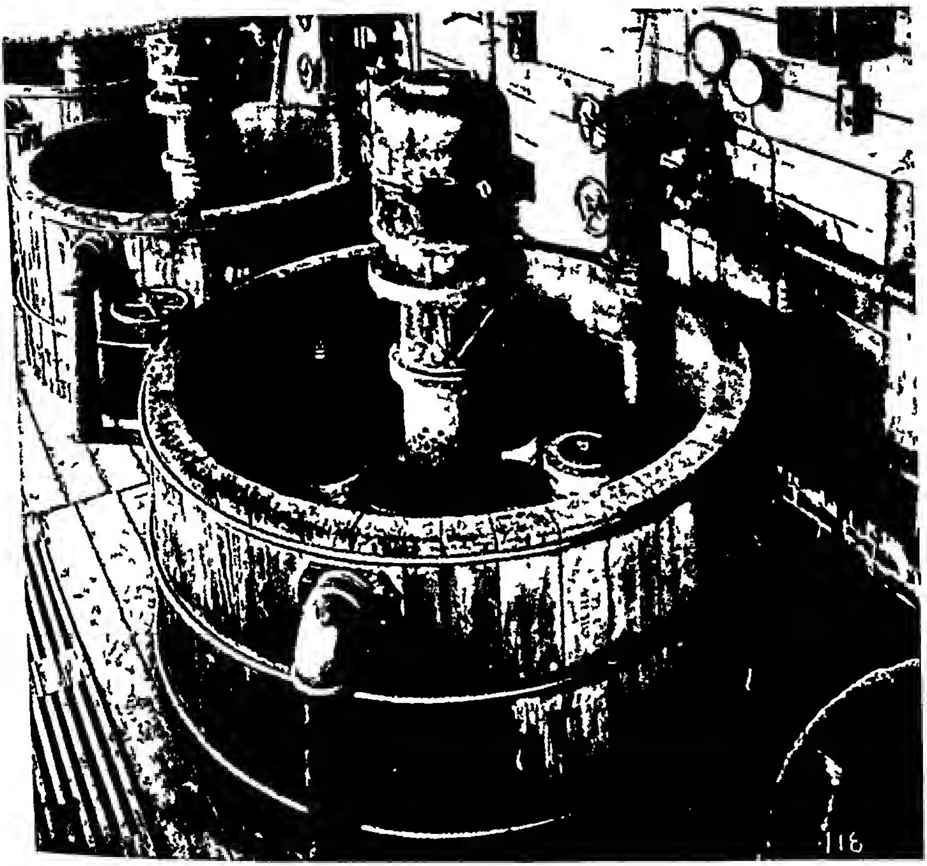


Fig 8 Installation of an Abbott top-yarn-dyeing machine

Company in 1929 under the name of the Abbott dyeing process This process found so much favor in the New England section that as early as 1932 the manufacturer was able to claim a productive capacity of over 25 million pounds yearly

The top-dyeing equipment comprises a specially designed gill box through which the top sliver runs (in an untwisted form) and from which it is then wound under tension on a perforated-metal dye spool The dyeing is carried out on this perforated metal spool which is locked in place over an orifice in a specially designed dye kettle In Fig 9 (showing a cutaway section of the dyeing machine of the Abbott process) it will be noted that the machine has a false bottom, and that the impeller is rotated from a perpendicular shaft driven from a motor

mounted on a perforated column wholly outside and above the kettle This perforated column with its motor assembly is readily removed as a unit

The loaded spools are placed over specially designed orifices in the upper bottom and the detachable plate clamp covering the upper opening of the spool is secured by the turn of a nut placed on the exposed upper end of the stay rod This holds the spool rigidly upright and seals securely both the upper and the lower openings of the spool, so that by necessity all circulation must pass through the perforations The barrel of the spool is large and the thickness of the material wound thereon is relatively thin The circulation is downward into the compartment formed by a false bottom and upward through the spool, returning through the perforated central column This circulation is designed to give a volume of flow, either cold or hot, nearly double that of other existing circulating equipments The velocity of the flow is decidedly low Light, easily handled, but effective covers prevent steam from escaping into the dyehouse

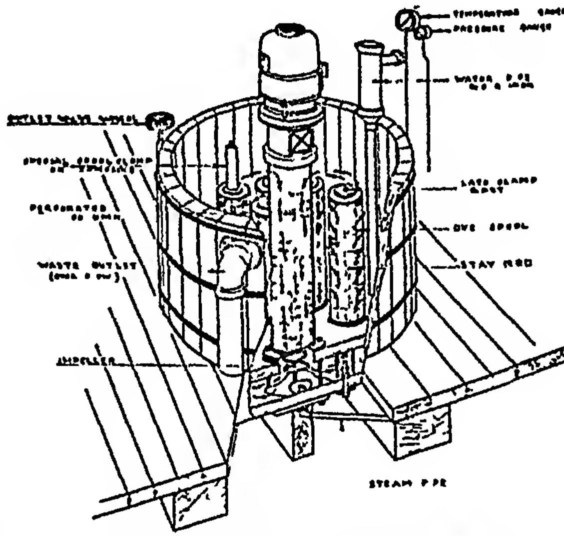


Fig 9 Cutaway section of Abbott machine

These kettles are made for two, six, or eighteen spools and may dye less than full capacity with perfect results The kettles are supplied in wood, with all aluminum or all stainless-steel fittings The Abbott dyeing machine is the only one that is constructed of an aluminum alloy, which has proven quite suitable for regular chrome dyeings

Pot- or Can-Dyeing Machinery

The pot- or can-dyeing system, which is considerably simpler, originated in Europe in the early 1900's but has been used in the United States on a large scale only since World War I It is favored in the Philadelphia and Passaic areas Figure 10 illustrates the English version

of this type. Normally, one ball is placed into a vertical can with suitable perforated lids and bottoms through which the liquor enters and penetrates the material. The machines are built with four, eight, sixteen.

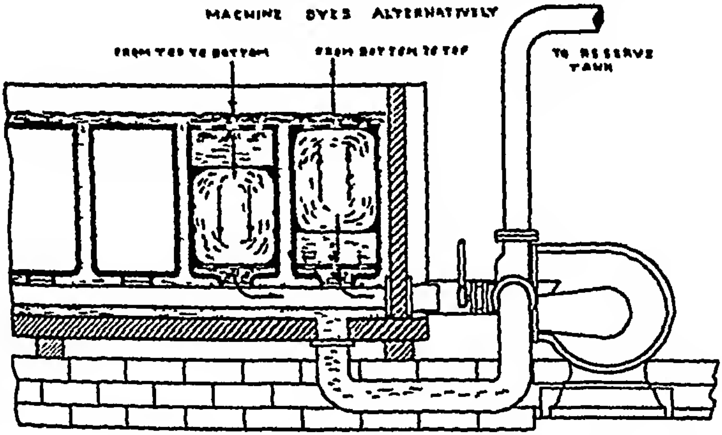


Fig 10 Can top-dyeing machine (*Callebaut and De Blicquy*)

Fig 11 Loading of a can top-dyeing machine
(*Courtesy Forstmann Woolen Company*)

or thirty-two cans, and have a capacity of 30 to 500 pounds The latest cans are made either from a glazed material (like porcelain) that is called Vitralite, or from stainless steel In this type of apparatus the presence of metal is so considerable that only the best alloy is suitable.

The advantages of these machines are many *1st,* quick loading and unloading two men may load and unload a thirty-two-pot machine in twenty minutes, *2nd,* the evenness of the dyeing and the penetration is of a high uniformity, and the top is preserved to such an extent that recombing is not necessary, *3rd,* flexibility in order to dye a smaller weight than the one for which the machine was intended, half of the cans are fitted with a device that stop them off by simply turning the cans half way around on their conical base

Yarn-Dyeing Machinery

The dyeing of yarn in machines is not done to the extent of raw-stock and top dyeing, because it is more difficult and needs special attention Apart from the fullest preservation of the material, and the avoidance of felting and crushing, the demand for greatest uniformity of the shades has to be met, as no blending is possible to correct differences in shades, as with stock- or top-dyed material Special consideration in yarn dyeing should be given to the selection of suitable apparatus, because the different systems vary considerably

Hank dyeing Yarn in form of hanks or skeins may be dyed in machines according to the packing system, the hanging system, or the spindle system As the names imply, in the packing system the yarn is packed into the apparatus and in the hanging system the yarn is suspended in the apparatus In the spindle system the yarn is dyed in the form of packages, cheeses, spools, etc In selecting an apparatus the same distinction must be made as in slub-dyeing machines, i e, those in which the liquor is forced through the material and those in which the material is taken through the liquor

Whereas in other countries, especially Europe, apparatus built on the principle of dye wheels (as the Klauder-Weldon machine already discussed under top dyeing) could not make any headway in the dyeing of yarn, this machine is still used extensively in the United States The large job-dyers do the scouring as well as the dyeing in this type of machine Reserve wheels that enable them to prepare the new load outside the machine are used In completing a dyeing the entire wheel with the dyed yarn is taken out of the machine and replaced by a new one, an operation which is done in few minutes

The general tendency is away from the principle of dyeing by moving the material in a stationary liquor Therefore, the new mechanical apparatus in which the yarn remains stationary and the liquor is agitated is favored. The same principle of construction prevails in yarn dyeing as discussed under stock and top dyeing Actually, the same machines are used with the exception that the carrying device may be different There are three main systems in use.

1. *Dyeing of yarn according to the packing system* The yarn is laid into the vat in layers and placed in alternate directions The hanks of the second layer are at right angles to those of the first, thus ensuring a uniform packing of the yarn and, at the same time, a more uniform penetration of the yarn by avoiding the formation of open channels This method is rarely used in the United States

2 *Dyeing of yarn according to the hanging system* The yarn is either suspended on narrow rods, sticks, or cords, and then is grouped into blocks which are placed in the machine The machine mainly employed is the Hussong machine (described under stock dyeing) Instead of using a cage, the top cover is provided with self-unloading yarn racks where the hanks are hung on sticks (Fig 12) These racks are easily lifted out of the machine with the help of a pneumatic lifting outfit and transferred to special trucks, where the yarn can hang until completely drained

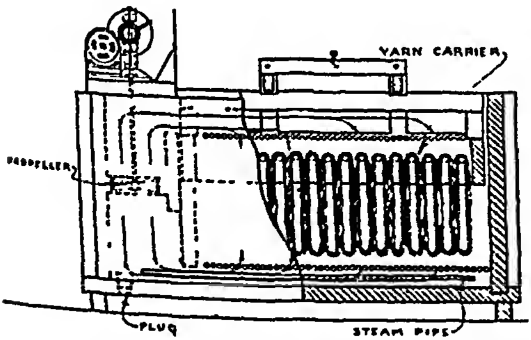


Fig 12 Diagram of Hussong skein-dyeing machine

3 *Dyeing of yarn according to the spindle system* In this system the yarn may be dyed in the form of cops, packages, cheeses, or spools The dyeing of cops is not very practical The dyeing of packages or cheeses is generally done in the same type of machines as described under stock dyeing The builders of raw-stock-dyeing machines furnish special yarn carriers (Fig 4), so that the machine can be used efficiently for stock as well as yarn dyeing These dual machines are of particular value in mills that manufacture stock and top-dyed goods with multicolored effect stripes Only small amounts of these effect yarns are needed and, therefore, the most economical way is to dye them in the yarn

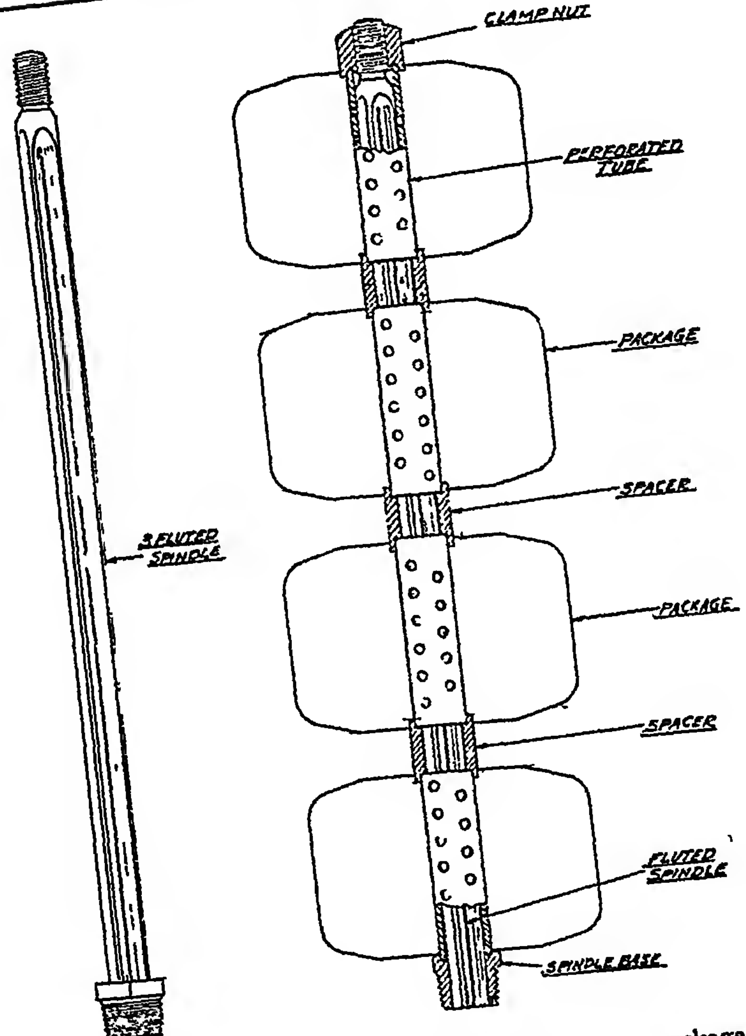


Fig 13 a) Fluted spindle b) Mounting yarn packages
Courtesy Venango Engineering Co, Inc

The carriers are built to accommodate from 24 to 500 packages, normally four per spindle These spindles are either perforated pipes, as described under top dyeing, or fluted metal rods with three or four ribs as illustrated in Figure 13 In making up the packages, the yarn is wound upon perforated rigid cardboard or metal tubes or spools or upon spiral springs covered with a knitted jacket Impregnated card-

board tubes have proven very suitable and most economical. Figure 13 illustrates one method of loading in the carrier system. Four packages and three spacers are dropped over each of the fluted spindles rising vertically from the bottom of the carrier

The spacers between each package are stainless-steel collars that connect the perforated tubes and avoid deforming of the packages by pressing or shrinkage, as well as possible leakage A clamp nut is screwed on top of each spindle to fasten and seal the whole column, thus preventing the liquor from going anywhere except through the yarn

When fully loaded, the carrier is lifted from the floor and lowered into the dye tub with a hoist When dyeing is completed the carrier is lifted out of the tub and the yarn vacuum-extracted and dried, while still on the frame The packages are not removed until ready for use

Dyeing in jackspools or large dye spools has become very popular in the United States because of its great time-saving factor Two processes are used, namely, the Franklin process and the Abbott process

In the Franklin process, the dye spools are wound from regular wooden jackspools (see Chapter 15), or they can be built from bobbins, cones, or parallel tubes exactly the same as a regular spool The yarn to be dyed is wound onto a jackspool with a perforated barrel These spools carry from 10 to 35 pounds of yarn, allowing great latitude in the weight of the lots to be dyed

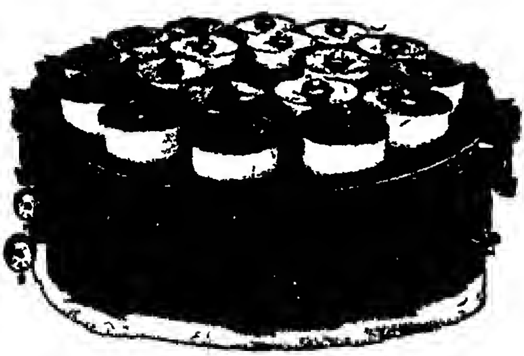


Fig 14
Franklin-process jackspool-dyeing machine.

The spools are placed vertically in the dyeing machine (Fig. 14) It takes less than fifteen minutes for one man to load a 500-pound machine The machine is provided with a heavy metal cover that is closed during the dyeing process The kiers of the machine are built of 4-inch cypress or entirely of acid-resisting metals

In the Abbott process, the machine already described under top dyeing with the same spindle can be used The winding of the yarn on the dye spool is accomplished in the same way as in the Franklin process Any load between 5 to 30 pounds may be placed on the spool

Machines for Drying of the Dyed Material

For proper drying, in whatever form—of the dyed stock, the dyed top, or the dyed yarn—drying machinery has to be provided In drying of raw stock, the same machines are used as in drying of scoured wool

The procedure to be followed after dyeing to restore the top or slubbing to the proper condition for drawing and spinning depends on the dye process and the handling of the process When dyed in hank form, the slubbing is rinsed in the dye machine, then extracted and dried in hank form in special dryers In the hank-dyeing process the production of neps by partial felting and curling of the fibers cannot be avoided and a recombing is necessary to remove these neps This is done by placing the hank around a broad flanged, hat-shaped arrangement of tin, mounted on a spindle, from which the end runs through rollers into a can From these cans, the end is then taken through gill boxes, which straighten and open the fibers, or effect a mixing of the colors, if required Afterwards the yarn is "punched" for the Noble comb or goes directly into the French comb

A sufficient rinsing cannot be given the top-dyed ball in the dye machine itself, therefore the rinsing is combined with the drying, gilling, and mixing by running the ball through a back-washer, especially built for dyed top

Instead of only two scouring bowls as built for back washing white top, the machine is provided with five compartments The first bowl is filled with an alkali-containing liquor (½ lb soda per 100 gallons) to neutralize any excess of acid, this is especially necessary for deep blacks dyed with sulfuric acid The next two bowls are filled with a very dilute soap solution of 4 to 8 ounces flake soap per 100 gallons Synthetic detergents are preferred when soft water is not available The last two bowls are supplied with soft water and act as rinsers The temperature of each of the five baths is kept around 100 degrees F The drying of the top is then accomplished by running it over perforated cylinders or it is carried on a wire apron In both instances it is dried with hot air A gilling operation finally follows for opening the fibers and to facilitate drafting in the succeeding operations When carefully handled by the dyer, the recombing of can-dyed top is not necessary

Without doubt, the Franklin and the Abbott drying procedure is the most economical, because after dyeing to shade and proper rinsing, the spools with their dyed contents undisturbed are taken from the kettle and, while still wet, are placed in the drier (Fig 15)

The spool is placed over a horizontal arm or stud, in principle the same as the spool is placed in the dye kettle, and in like manner it is

locked over a special orifice at the rear of the drying compartment and held in rigid position by a plate clamp and hand screw at the outer end of the spool All air, by reason of this arrangement, passes through the spool perforations

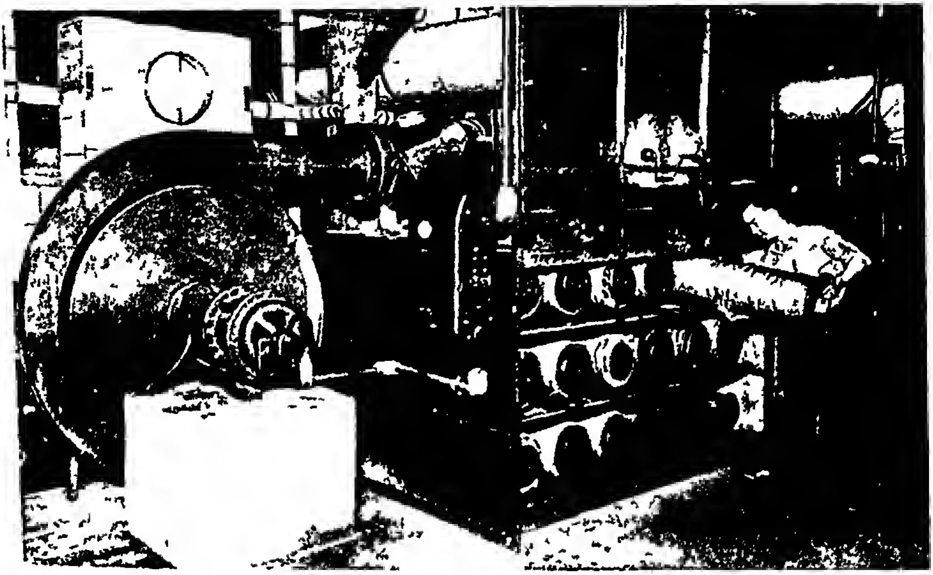


Fig 15 Top- and yarn-drying apparatus with blower
(*Courtesy Abbott Machine Company*)

The drier accommodates eighteen spools at one time (500 to 540 pounds) or, as with the dye kettle, the spool openings may be blocked off In this case an unperforated "dummy" spool is used, so that any number of spools may be dried In operation, the air is blown through the spools and expels the water This is accomplished in a very few moments, then warm air is introduced and passed through the material until it is dry Fine top will be dried to a definite moisture content in about three hours, coarse top and yarns in from one to one and one-half hours Back-washing is dispensed with entirely After drying, the spool is placed in a six-spool creel and condensed either five or six to one through a plain balling gill, and thence to the drawing proper

For the dyed yarn the drying procedure in the Franklin and the Abbott process (in which the yarn is dyed on perforated spindles) is exactly the same as described for the Abbott-process dyed top After drying, the yarn may be run from the spools on a rewinder to a dresser spool or it may be placed in a jackwinder and run onto bobbins, or it

may be run on the cheese or cone rewinder directly into the desired package form

Obermaier follows a similar drying system for the package-dyed yarn The carrier, loaded with 18 to 72 cheeses, is lifted out of the dye kettle and first placed on top of a vacuum tank In a few minutes the excess water is extracted down to approximately 50 per cent moisture in the yarn The carrier is then connected with a large blower unit and warm air blown through the spools until they are dry

Piece-Dyeing Machinery

Piece dyeing is the only dyeing process for which the machine builder has not yet succeeded in constructing a satisfactory machine in which the dye liquor is circulated and the goods kept stationary Piece goods, whether all wool, all worsted, or composed of mixtures of cotton, wool, and other fibers, are dyed in the same type of machine The dye beck consists of a rectangular box with a curved back sloping inward toward the bottom A slat reel or winch that is mounted on the top, lengthwise of the machine, is usually driven by individual motors on each machine

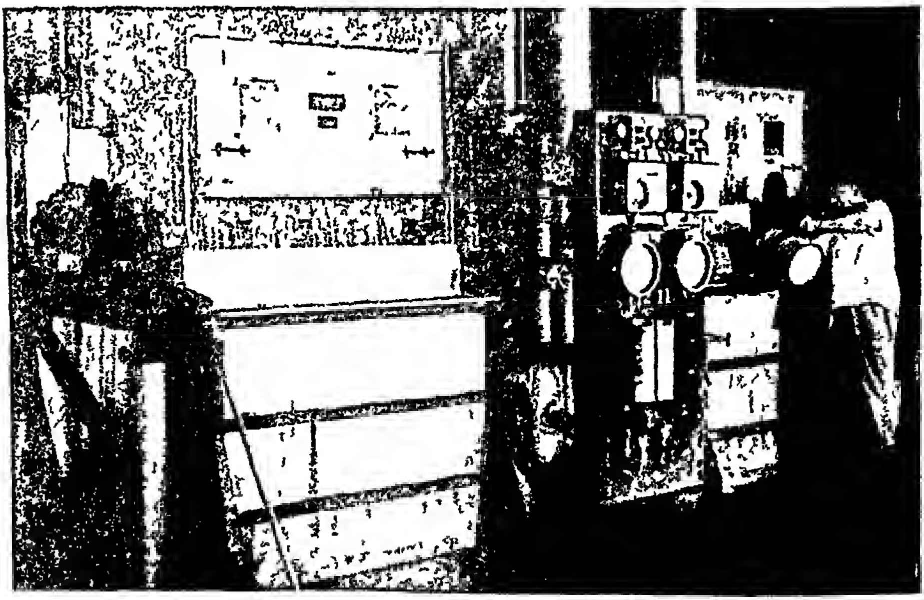
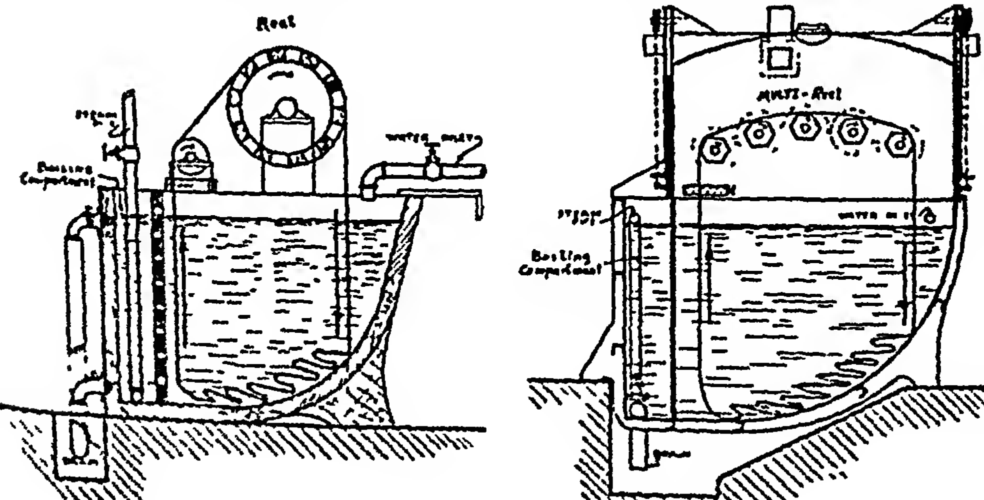


Fig 16 Multireel stainless-steel dye kettles (*Courtesy Forstmann Woolen Company*).

The piece is sewed end to end over the reel so that, when the reel revolves, the pieces move continuously through the dye bath Figures 16 and 17 illustrate such a machine The average kettles are built to carry from two to four, or eight to twelve pieces, depending on the weight, each measuring from 50 to 75 yards in length The kettle is heated by an open steam pipe in front of the machine, which is separated from the actual dyeing chamber by a perforated partition which prevents the cloth from coming in direct contact with the steam and allows the bath to become heated uniformly. These machines have been constructed of wood, but the present trend is toward all-metal machines Monel metal has been used successfully for lining wooden machines, but stainless steel (Enduro 18-8-SMo) has been found to give the best results The use of metal is much more satisfactory than wood because the machine can be readily cleaned after use, and light, bright shades can be dyed after blacks or other heavy colors with no alteration of shade as in the case of wood For economical reasons the machines today are totally enclosed In the last few years quite a large number of dye houses have *replaced their old open kettles* with totally-enclosed, stainless-steel dye becks The saving on steam consumption alone is 30 per cent or more



Wooden piece-dye beck Multi-reel stainless-steel dye beck

Fig 17

A new and compact reel has been developed consisting of hexagonal stainless steel rollers mounted on an arch in the kettle itself The number of rollers varies from three or more according to the size of the

machine The new reel has the advantage of keeping the cloth in the dye liquor most of the time and avoids an unnecessary stretching of fabrics such as fine crepes

For proper observation of the pieces during dyeing, the top of the machine is fitted with an acid-proof light Sliding doors in the back and the front have small windows The front door is normally set back, allowing the dyer to make addition of dyestuffs or chemicals without opening the machine The drain valves are outside of the machine A recent advance is to heat the dye liquor through a system of hot-water pipes instead of by direct steam

To avoid unnecessary felting of delicate goods, machines are fitted with low- and high-speed drives For greatest security and accuracy, automatic time- temperature- and steam-control systems are considered a necessity

Continuous woolen piece dyeing No other dyeing method lends itself so readily to continuous operation as does piece dyeing Whereas continuous dyeing of cotton, rayon, and mixed piece goods has been successfully solved, the only really successful *continuous woolen piece goods dyeing* on a large scale was done during World War II in the dyeing of the 11-ounce Navy flannel with indigo The difficulties encountered in developing this process at the Hampshire Company were reported by George Linberg

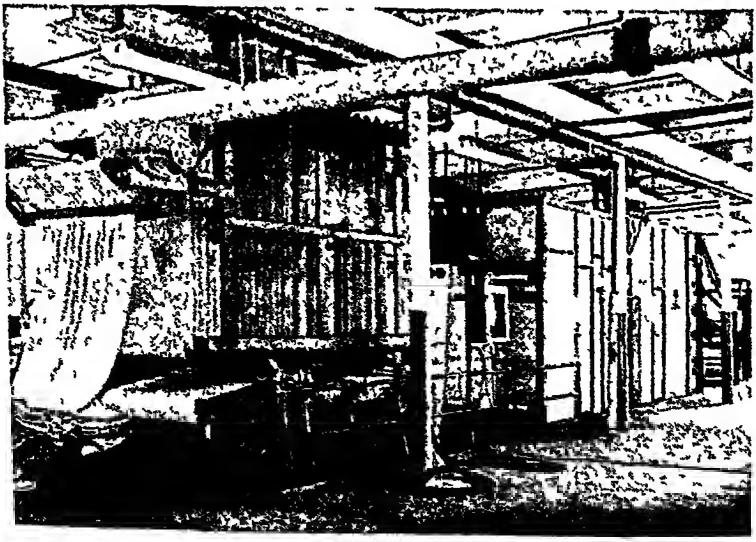


Fig 18 Continuous woolen piece dyeing (*Courtesy the Hampshire Company*)

The essential parts of the machine are a rectangular, 3000-gallon tank, 70 inches wide, through which the pieces pass in full width, threaded over and under a series of guide rollers, fully immersed in the reduced indigo liquor Above the tank is a sky frame which is needed for the proper oxidation between dips (See Fig 18) To produce the full shade, the flannel is given two dips of three minutes each, with a five-minute skying or oxidation after each dip Two sets of squeeze rollers are necessary to recover the excess dye liquor and to assist in the proper penetration of the dye through the cloth The speed of the machine is 10 yards per minute and the goods coming off the end of the machine are plaited on trucks After dyeing, the cloth is scoured in regular dolly washers Linberg stated that continuous piece dyeing of woolen goods with indigo is but a prelude to a much more ambitious program of the application of vat colors to all wool fabrics and wool and mixed fiber materials To include acid and chrome colors in this program, William Wentz of the Du Pont Company designed the multilap continuous processing machine The first model of this machine has produced promising results but there is still a long way to go before a simple continuous dye method for woolen and worsted piece goods can be evolved

THE MATCHING OF COLORS

Henry Millson

Dyeing is an art Years of study and practice are required to become proficient in color matching There are certain basic principles, however, that govern the reproduction of various shades and these will be discussed in detail

Ordinary daylight, which appears white to the eye, is a mixture of all the colors in the spectrum This fact is demonstrated every time a rainbow is seen in the sky The reason that a piece of white wool appears white to the eye is that when daylight strikes the sample all the color components are reflected back to the eye If some components of white light are absorbed then the sample no longer reflects back all of the colors in the spectrum, and it will therefore appear colored The function of a dye when added to white wool is to absorb some of the white light components and thereby give it color

Subtractive Colorimetry

The system of colorimetry that is of most use to the practical dyer is known as subtractive colorimetry If to samples that initially are white

are added various coloring materials such as dyes, some parts of the white light are *subtracted out* from the light that is reflected back to the eye If a yellow dye is put onto wool, part of the white light is absorbed, if a red dye is put onto a second sample of wool, another part of the white light is absorbed, and if a blue dye is put onto a third lot of wool, still another part of the white light is absorbed If all three of these dyes are put onto one sample of wood, and they are sufficiently heavy to absorb all kinds of visible light, the net result is, therefore, a black Since these three colors are adequate to absorb all the kinds of light and produce blacks, they are known as *primary colors* If red dye and blue dye are put into wool, the resulting color in most cases will be purple If a red dye and a yellow dye are put onto wool, the resulting color will in most cases be an orange, and if blue dye and yellow dye are put onto wool, in most cases the resulting color will be green

In theory, all colors can be matched with the *three primaries* However, in practice it will be found that in general a mixture of a red dye and a blue dye, which will produce a purple, will not produce a brilliant purple equal to that produced by the use of a single dye Therefore, it is not correct to say that all shades can be matched by mixing the primaries, red, blue, and yellow Nevertheless, this concept of the three primary colors and the resulting mixtures is of use to the dyer In selecting the colors which a dyer should have on hand, the first consideration must be given to the classification of dyes Thus, it may be necessary to produce many shades of wool dyed by a particular dyeing method and all the colors must have certain fastness requirements. Such a classification will greatly limit the dyes it is possible to use Within this group, however, it is very important to have the three primary colors, e g, red, yellow, and blue With these three primary colors, most of the shades encountered by the dyer can be matched There are two important exceptions to matches made this way one is a standard shade produced with a single dye of great brightness that cannot be matched with any combination of the three because it is too brilliant, the other exception is in dyeing dark shades It will usually be found more economical to dye blacks with a black dye than to attempt to dye blacks by mixtures of three primaries This same economical consideration applies to navy blues and other dark colors Nevertheless, even in the case of these dark colors, it is handy to have the three primary dyes available for shading purposes

Hue

A second important application of the principle of subtractive colorimetry is that it gives a nomenclature to colors A circle may be drawn

with the word *black* at the center and the words *red, orange, yellow, green, blue,* and *purple* around the outside of the circle in that order. This illustrates how many of the common colors can vary in shade For instance, traveling around the circle in one direction, from yellow one arrives at green, while traveling around the circle from the other direction, one arrives at orange If, now, a number of yellow samples that differ in hue are examined visually, it will be found that they, too, vary accordingly as they are more toward the orange color or more toward the green color In an everyday situation, when a dyer has a standard yellow shade to match, the first shade may vary in hue from the standard This variation may be described by the dyer as "redder" or "greener," which means that the sample deviates in appearance in the same manner that an orange sample deviates from yellow, or in the same way that a green deviates from yellow Table 2 gives the deviations in hue which the brighter samples may exhibit

TABLE 2 DEVIATIONS IN HUE

Red	Bluer	Yellower
Orange	Redder	Yellower
Yellow	Redder	Greener
Green	Yellower	Bluer
Blue	Greener	Redder
Purple	Bluer	Redder

It will be noted that there are two very important colors omitted from Table 2 One is black and the other is brown These are colors that are made by mixtures of all three primaries and, therefore, they can deviate in shade in more than the two directions to which the colors in Table 2 are limited The nomenclature for deviation of these colors is less well standardized, but one system in fairly wide usage is that blacks may vary in one manner by being blue (or bloomy), which is an indication that the blue primary is present to the greatest extent, or the blacks may vary by being jet or by being green, which is an indication that the yellow primary is present to a greater extent than it is in the bluer sample; or the black may be a reddish black or a plum black, which is an indication that there is a greater amount of red present than in the other two samples A brown is really a dull orange and, accordingly, is ordinarily described as being a redder brown, a yellower brown or, in the event that the blue primary is present in less amount, it may be a brighter brown.

A third application of the subtractive color system is in giving the colorist a clue as to the proper colors to add to correct the shades For instance, when an orange sample is prepared, it may deviate from the

standard by being redder in shade With an understanding of the color-mixing circle, it is obvious that both the standard orange and the sample orange representing the lot are essentially mixtures of red and yellow dyes It should also be clear from a consideration of the color circle that the smaller the amount of yellow in the mixture of red and yellow, the redder the sample will be, and, conversely, the smaller the percentage of red, the yellower the shade will be In considering these two samples, therefore, it is clear that the sample of orange taken from the lot contains too high a proportion of red dye The way to correct this shade is, therefore, to add yellow dye that will restore the proper proportion of red and yellow in the sample In this way, the proper hue of orange will be created Similar considerations show that in Table 2 if a color in column 1 is off-shade from standard as indicated by the description given in column 2, then the primary dye that must be added is given by the color listed in column 3 This statement is not quite true because sometimes green is listed in column 3, but, in any event, to change a hue in one direction around the circle, a color must be added that is farther around the hue circle than the standard

Strength or Weight of Dyeing

There are two other equally important factors in color matching in addition to hue One of these relates to the total amount of dye present and may be called the "strength" or "weight" of the dyeing Thus, in the example above, it might be clear from a consideration of the hue circle that the sample was redder in shade than the standard orange and it might be clear that a yellow had to be added to correct the hue, but, unfortunately, if enough yellow were added to match the hue, then the total amount of orange dye present, that is, the total amount of dye that produced the orange color, might be greater than the amount of dye producing the orange standard This would mean that the sample had been overdyed and it would be necessary to strip off some of the color in order to arrive at the correct shade This is a difficult, expensive, and not wholly satisfactory process and, therefore, it is customary for the experienced color matcher or dyer to approach the match to the standard from the light side, that is, he adds dyes in the proportion he believes necessary but ordinarily does not add the total amount of dye the first time Then, by visual examination and comparison of the standard against the batch sample, he can ascertain whether additional dye in the proportion previously used must be added or whether the proportion should be altered in order to correct the hue as he approaches the final depth of shade

Brightness

A third, and equally important aspect of color matching, is brightness Brightness is that aspect by which a cherry red differs from a brick red In terms of the primary system, a brighter color is one which contains less of the dye located directly opposite to it in the color circle. Thus, an orange sample that is brighter than standard contains less blue than standard If a sample of orange differs from a standard orange by being brighter, it is possible to add a very small amount of blue and correct it for the off-shade Adding the blue will not make the orange redder and will not make it yellower but will only make it duller If the sample is duller than the standard to begin with, it is theoretically necessary to remove some blue dye from it but, since this is usually impossible, if a dyeing has proceeded to this stage it is impossible to bring it to an exact match without stripping some color off Accordingly, the experienced dyer will try to approach the shade from the bright side rather than from the dull side

It is, therefore, necessary for the dyer to bring his lot of wool to the standard shade in regard to all three aspects, e g , hue, strength or depth of dyeing, and brightness Usually years of experience are required to develop an ability to match shades but in this work the concept of the red, yellow, and blue primary colors and the concept of the color circle will be helpful

Color-Matching Instruments

There are electrical colorimeters and spectrophotometers on the market, and it is sometimes claimed that these instruments are useful in matching colors There is, however, one serious drawback to dependence on these instruments in matching colors Nearly all of the science of colorimetry when applied to such instruments is based on a different theory of color mixture known as the *additive* system This system starts with complete darkness and to it is added colored light By adding three colored lights in different proportions, all of the various shades may be obtained The principles of additive and of subtractive colorimetry are so similar that the two systems are sometimes confused. The additive system is of very little use to the dyer because in his work he does not begin with darkness and add colored light but, instead he begins with a white material and adds to it a dye

There are, however, three very important applications in which colorimeters and the science of additive color mixtures may be of ad-

vantage to the dyer One application is the maintenance of permanent standards The colorimeter can measure a sample and get absolute data It can measure the same sample a year later and determine whether or not the sample has changed, while it is impossible for the dyer to remember the exact color over a period of a year In other words, the work of a dyer is always the relation of one color to another, and the problem of getting an absolute color measurement is best entrusted to instrumentation

A second application is in the establishment of color tolerances Thus, it is possible to state in numerical terms the degree by which one sample may deviate from another and still be within predetermined tolerances Although the dyer is able to look at two samples and state that there is a difference, there may often be an argument as to whether the observed difference is of large enough magnitude to be commercially significant or not Such differences can be evaluated with instruments

A third application of instruments is in the evaluation of changes brought about by the various factors For instance, in testing for light fastness, it is customary to expose a sample to light until a change has been produced in the sample Here again, there may be some difference of opinion as to the magnitude of the change and an instrument may be used to evaluate this difference and set up allowable fastness requirements

There are some instances where a proper interpretation of instrumental data may be of assistance to the dyer in other applications than the three mentioned but these are the ones that are well established It is, therefore, of interest to note that use of a colorimeter or a spectrophotometer should complement the dyer's work, but since it is unable to choose the proper combination of dyes and since at present it does not allow of rapid color matching, there is no indication that instruments will ever replace the dyer

There are many other factors that are of importance in color matching One factor is the color of the undyed wool Raw wool possesses natural dyes which give it a yellowish color Some of these natural colors can be removed by bleaching but even bleached wool contains some residual coloring material Another factor is the difference between the result obtained by dyeing wool and by mixing or blending different colored wools For instance, if a sample of wool is 4 per cent dyed with a black dye, a very dark shade may be produced If some of this wool is mixed with white wool in a 50 to 50 proportion, the mixture will be lighter in color than the 4 per cent dyed wool This mixture will contain 2 per cent of dye on the average If, now, another sample is prepared with wool dyed at 2 per cent, again a sample will be available

that will contain 2 per cent of dye If a comparison is made between these two samples, each of which contains the same amount of dye but one containing it in every fiber whereas the other contains twice as much dye in some fibers and none in others, it will be observed that the 2 per cent dyed samp'e is darker in color than the 2 per cent blended sample

Another factor is the ability to determine colors, which may vary with the individual About 4 per cent of men are color-blind to some degree. This means that some men can determine color differences more easily than others Another factor is that of the light source In general, a good color match should match under both daylight and artificial or tungsten light, although in some special cases it may be satisfactory to arrive at a match under one illumination only.

Eye fatigue is an important factor If one looks at a bright red sample for a period of time and then turns and looks at a white ceiling, a spot similar in dimension to the red sample, but of a complementary color, namely, green, will appear on the white ceiling Psychological factors such as these, which are due to eye fatigue, are important in color matching The angle at which a sample is viewed is very important Thus, in comparing two pieces of cloth, it is important to have the weave of the cloth oriented identically for each piece Widely different co'ors are often apparent with different angles of viewing and illumination The area viewed is important Thus, it is ordinarily easier to distinguish small color differences if the two areas in juxtaposition are large than if the two areas are small It is also very important to have the two colors in juxtaposition, as two colors separated by some space are very difficult to judge with any degree of refinement

Fluoresence is sometimes a problem, although most of the fast-to-light dyes on wool are not fluorescent A fluorescent sample will vary in apparent color more radically with change of illumination than will a nonfluorescent sample, and in many cases will also vary more widely with a changed angle of view Fluorescent colors are also troublesome in that they deviate from the subtractive system of colorimetry as described here Thus, it is possible for a red dye which fluoresces green to make the sample appear greener It is contrary to the subtractive color system to have a red dye make a sample appear greener

The color may vary with moisture content This is particularly troublesome when a wet sample recent'y removed from the dyeing kettle is compared with a dry standard Some of the more expert colorists can determine fairly well whether a sample is a match even when one is wet and the other is not but the match should always be checked with the two samples having the same moisture content

Phototropism is also a factor in color matching. Phototropism is a phenomenon in which a sample that has been exposed to light appears different than when it has been kept in the dark This is distinguished from the phenomenon of fading by its reversibility Thus, a phototropic sample can be made to change under the action of light and recover in the dark and the process repeated many times, whereas a sample which has truly faded changed its color in the presence of light but does not return to its original shade.

DYEING PROCEDURES

Generally speaking, there are three classes of colors used for dyeing wool in all forms, namely·

1 Acid and milling colors
2 Chrome and mordant colors
3 Vat colors

Each group derives its name from the method of application.

Dyeing with Acid and Milling colors

As a whole the acid dyes produce bright shades of satisfactory general fastness They are employed most commonly in women's wear, sweaters, upholstery yarns, bathing suits, and many other types of woolen materials where the ultimate in fastness is not essential

The method of dyeing from an acid bath varies in accordance with the nature of the dye and the goods to be dyed These colors may be divided into five groups, according to their application In each case, the amount of acid recommended is that which will effect a uniform distribution of the dye within the dyeing period and, at the same time, secure an economical exhaustion of the bath When dyeing is completed, most of the color will have been absorbed by the fiber, and the bath will generally contain little or no color

Method 1 The dyes used in this method are such as will level easily at the boil from a strongly acid bath Level dyeing colors distribute themselves uniformly through the material and the individual wool fibers. At low temperatures certain fibers in a blend of wool will absorb dye rapidly and become quite heavy during the early stages of dyeing, but at the boil they release the excess so that it is available for other fibers which absorb dye more slowly. These dyes have the peculiar but

important property of boiling on and off the fiber in an acid bath. This exchange of dye molecules between the wool fibers continues at the boil until equilibrium is reached, at which time each fiber will have absorbed about the same amount of dye The color is applied according to the following procedure

The dissolved dye is added to the bath, usually in a volume of 20 50 1 in relation to the weight of the material Then the dye bath is set with 5 to 10 per cent calcined Glauber's salt, 3 to 4 per cent of sulfuric acid (96%—66° Bé) or 8 to 10 per cent bisulfate of soda (niter cake), depending upon the amount of dye used Ninety per cent formic acid may be used in place of sulfuric acid because it produces better levelness and penetration with some acid colors When dyeing light shades it is often good practice to replace sulfuric acid with the same amount of formic acid or 4 to 8 per cent acetic acid (28%). All percentages of chemicals and agents are calculated on the dry weight of the material The goods are entered at 100 to 120 degrees F. and then raised to the boil in one-half to one hour and boiled for three-quarters to one and one-half hours The wool dyer usually prefers to add all the acid required in the beginning so that intermediary additions are unnecessary.

Method 2 In this process colors are used that are dyed from a weak organic acid bath and, when necessary, complete exhaustion of the bath may be obtained by further additions of organic acids or with sulfuric acid This type of dye has a greater affinity for wool than the ordinary acid colors, and, therefore, must be handled with care These dyes are sometimes called acetic acid dyeing colors and are applied according to the following procedure

The goods are entered at 70 to 80 degrees F into the bath containing 3 to 5 per cent acetic acid (56%) and 5 to 10 per cent calcined Glauber's salt The bath is raised to a boil in one to two hours and boiling is continued for three-quarters to one hour more If necessary, especially in heavy shades, 3 to 5 per cent acetic acid or 1 to 2 per cent formic acid or ½ to 2 per cent sulfuric acid are added gradually and the goods boiled for another half to three-quarters hour The acetic acid necessary to start the dyeing may be replaced on less sensitive dyes by one-fourth the amount of formic acid In machine dyeing, it is advisable to commence dyeing with 5 to 8 per cent acetate or sulfate of ammonia and 1 to 2 per cent acetic acid For "shading," the extremely level dyeing colors suitable for Method 1 may be added directly to the boiling bath On the other hand, if the weak acid dyeing group is used for shading, the bath should be cooled down before adding more dye and then gradually raised again to the boil and boiled for twenty to thirty minutes,

Method 3. In this group belong the dyes that require only a small amount of acid for exhausting the dye bath, as they are very apt to dye spotty and uneven Because of this, many dyers prefer to use ammonium sulfate, ammonium acetate, or dihydrogen ammonium phosphate in place of acetic acid Dyes in this class have a pronounced affinity for wool and the salts listed are used to obtain better penetration and levelness These colors must be dyed uniformly from the beginning to the end of the dyeing operation because they do not level well. Such dyes have greater affinity for the wool fiber than for the dye bath and consequently they do not leave the fiber once they have been absorbed.

Method 4 This procedure is carried out in a neutral dye bath with 5 to 10 per cent calcined Glauber s salt only or with the addition of 1 to 3 per cent of ammonium sulfate.

Method 5. This process is applied to a group of dyes which have chromium in their molecule and hence are called metalized dyes In this group belong the Neolans of Ciba Company, the Palatines of General Dyestuff Corporation, the Calcofasts of Calco Chemical, the Glycolans of Geigy Company, the Chromolans of National Aniline, the Chromacyls of E. I. DuPont de Nemours and the Vitrolans of Sandoz Chemical Works Metalized dyes are used especially for dyeing piece goods, men's wear, loose wool, tops, knitting yarns, and carpet yarns The metalized dyes are especially valuable for coloring unneutralized carbonized stocks and for equalizing the different affinities of wools in a blend

The dye baths are set according to the desired depth of shade and ratio of goods to the liquor with 5 to 10 per cent sulfuric acid (66° Bé) and the well-dissolved dye. The goods are entered at 100 degrees F , run for ten minutes without steam, and raised to the boil in one-half to one hour and boiled for at least one and one-half hours To obtain maximum levelness and color value the dye bath is set according to the ratio of the liquor, and the following quantities of sulfuric acid (66° Bé) will be required: about 8 per cent for 1 ·30 liquor, 9 per cent for 1:40 liquor, 10 per cent for 1 ·50 liquor.

With fairly deep shades it is advisable to commence dyeing with only two-thirds of the total quantity of acid, the remaining third being added when the boiling point is reached After dyeing, the goods must be thoroughly rinsed The addition of 5 per cent of acetate of soda to the rinsing bath is advisable for neutralizing purposes

There are often objections to the use of this group of dyes, because of the high amount of sulfuric acid necessary for proper color development. Various agents are on the market which enable the dyer to reduce the necessary acid by one-third to one-half. Such agents are Calcofast salt MD, Palatine salt O solution, and Neolan salt II.

Shades produced by Method I may be lightened and corrected by adding Glauber's salt. It may be necessary to run the dye bath half down, fill up with water, add Glauber's salt, bring to the boil, and boil for thirty minutes. If the material is light enough in shade to be corrected by adding dyes, additional dyes are fed into the dye bath, followed with a feed of acid. When the dyeing is too dark and off-shade, it is often good practice to correct the shade by boiling dyed and undyed materials together in a fresh bath to which is added 10 to 20 per cent of calcined Glauber's salt. Some of the color will boil off the dyed goods and go on the undyed. The equalizing action of the dyes will be speeded up if acid is added to the dye bath, as this will increase the affinity of the undyed material for color and improve the levelness of shade.

When these procedures fail to correct the condition, 1 to 2 per cent ammonia for 100 gallons is sometimes added to neutralize the acid in the wool and in the dye bath, whereby most of the dye is stripped from the wool fibers. The lot is then redyed to shade in a fresh bath.

Shades produced with milling and similar colors in the nonleveling and acid-sensitive classes are much more difficult to correct if they are uneven or the shade is too heavy. Boiling in a fresh bath containing Glauber's salt and ammonia will sometimes correct unevenness and reduce the depth of shade, so that correcting dyes may be added.

When moderate methods fail to correct the shade, the lot should be redyed into a darker shade or stripped with hydrosulfite or one of the sulfoxylates.

Dyeing with Mordant or Chrome Colors

The principle underlying the dyeing of mordant colors is that, in ad-

dition to acid and Glauber's salt, a metal compound is required to combine with or fix the dye on the wool and to develop the shade and fastness properties The action is briefly this The acid combines first with the fiber, the acid wool is then able to take up and unite with the dye By adding the metallic mordant this acid-wool-color compound is converted into an insoluble metal complex of the dye which is chemically united with the protein fiber Since chrome salts are the major compounds used for this purpose, these dyes are often referred to as "chrome" colors The mordant or chrome colors may be applied by four different methods commonly known as top-chrome, metachrome, Calcomet, and bottom-chrome methods

The chrome colors are used extensively for producing particularly fast shades on loose wool, top, yarn, and piece goods, wherever maximum fastness to the various manufacturing processes and wear is essential Generally speaking, most of the men's wear goods are dyed with these colors Compared with acid colors, the chrome shades as a whole are not as brilliant

1 *Top-chrome or after-chrome method* This process is based on the ability of wool to absorb certain dyes such as acid colors from an acid dye bath and their subsequent conversion to fast dyes by a treatment with potassium or sodium bichromate Chrome alum or chromic fluoride and sulfate of copper are sometimes used for special effects Sodium or potassium bichromate is generally used because it is suitable for the largest number of chrome dyes and at the same time produces the fastest shades

When using bichromate, the dye bath is set at 100 degrees F with 5 to 10 per cent calcined Glauber's salt and 2 to 4 per cent acetic acid (56%) together with the well-dissolved dye The temperature is then raised to a boil in about one hour and boiled for one-half to one hour more Then if necessary, another 2 to 4 per cent of acetic acid is added and boiling is continued for another one-half to three-quarters of an hour until the bath is exhausted The liquor is now cooled to about 180 degrees F and the dissolved bichromate is added slowly Again the temperature is raised to a boil and boiling is continued for another half to one hour to develop the shade The quantity of bichromate necessary for the developing of the shade normally amounts to less than one-half the quantity of dye used However, the amount of bichromate used should not be less than 0 2 per cent or exceed 3 per cent of the dry weight of the goods For blacks the quantity of bichromate used depends on the nature of the dye and, as a rule, it is one-third of the dye used Particulars are given by each dye manufacturer on this point In dyeing loose wool, Glauber's salt may be omitted.

Some chrome colors are improved by the addition of formic or even sulfuric acid, and when applying these colors 1 to 3 per cent of formic acid (90%) or 1 to 2 per cent sulfuric acid is diluted and added slowly to the dye bath after which boiling is continued for thirty minutes.

Recent studies have shown that most dyers use too much bichromate in after-chrome dyeings. Some colors can be after-chromed with one-half to three-quarters per cent bichromate in medium shades. The pH of the chroming bath plays an important part in the efficient use of the bichromate. A pH of 5 or slightly lower gives excellent results. Use of minimum quantities of chrome has produced dyeings with greater brightness, improved fastness to light, softer wool, and less loss of tensile strength.

Chromium fluoride is used chiefly in piece dyeing to develop certain fast navy blue shades. Alum developers are used in the production of fast-to-light-and-milling madder shades with alizarin reds. Copper sulfate is used in piece dyeing for certain blue shades.

For so-called "combination blacks" developing is accomplished with ferro and copper sulfate. This process is especially used for suitings and combines the advantage of goods dyed with ordinary acid blacks and those dyed with logwood. Both are applied in one and the same bath. The dye bath is set, according to the hardness of the water, with ⅔ per cent oxalic acid, 2½ to 5 per cent of an acid black, 20 to 35 per cent of logwood chips or 3 to 7 per cent of logwood extract (liquid) or a corresponding small quantity of logwood extract (solid). The whole bath is boiled up well, and the wet goods are entered, boiled for one hour, and 6 to 8 per cent ferrous sulfate and 3 to 4 per cent copper sulfate added and developed by boiling for three-quarters to one hour. For goods that are difficult to penetrate, the initial temperature should not exceed 120 degrees F. Cheap navy blues may also be produced by the same process, using a combination of logwood and acid violet. The disadvantage of the "top-chrome method" for the beginner is that normally the chrome dye undergoes a distinct color change when treated with the mordant and the final shade is not obtained until the mordant has been permitted to react with the dye. However, this is an economical method and produces shades with excellent fastness on a wide variety of goods.

2. *Metachrome or chromate method.* In this process the dyeing is simplified by adding the color and the metachrome mordant to the dye bath at the same time the dyeing is started. The metachrome mordant is usually a mechanical mixture composed of sodium or potassium bichromate and ammonium sulfate. It can be prepared in the dye house or may be bought already prepared from the manufacturers. This mordant pos-

sesses the property of liberating acid by slow and uniform decomposition, thus effecting a very gradual absorption of the dye by the wool. The chromic acid that is liberated at the same time combines with the dye on the fiber in such a way as to prevent the premature chroming of the color still remaining in the dye bath, and thus precipitation of the dye is prevented

As a rule, metachrome mordant is used in the same amount as the dye but rarely less than 2 or more than 8 per cent The temperature of the dye bath is brought to 100 degrees F after the material is wet out and ready for dyeing The mordant is added first, followed by the dye, and the lot is run without steam for ten minutes The bath is raised slowly to the boil in one hour or longer and boiled for one to one and one-half hours If the bath is not sufficiently exhausted, small additions of ammonium acetate, ammonium sulfate, or acetic acid are made and the boiling continued for another half hour or until the desired shade is obtained

3 *The Calcomet method* A new and improved metachrome method giving excellent results has been developed recently A number of important chrome dyes cannot be applied by the ordinary metachrome procedure and therefore they must be dyed by the top- or bottom-chrome methods With the advent of the Calcomet method, the range of metachrome dyes has been enlarged by making it possible to dye these colors by a modified metachrome procedure

One of the important facts established during the development of the Calcomet method was that the starting pH is of paramount importance in all metachrome processes For best results, the bath must be on the alkaline side at the start of the dyeing operation, preferably about pH 8 0

The dye bath is set at 110 degrees F and is charged with sufficient ammonia (usually 1 to 2% of 26°) to bring the starting pH to 8 The Calcochrome dyes are added to the bath followed by 3 to 4 per cent of magnesium sulfate and 0 7 to 1 5 per cent of sodium or potassium bichromate, 1 to 3 per cent of Calcomet salt L is added, and the lot run for ten minutes

The bath is brought to the boil in one to one and a half hours and boiled for one to two hours If further exhaustion is necessary any of the following may be diluted well with water and added slowly ammonium sulfate, ammonium acetate, magnesium sulfate, or small quantities of acetic acid after which boiling is continued for thirty minutes

The Calcomet process yields richer and more solid shades Skitteriness and fiber selectivity are considerably reduced or eliminated by this

method and the fastness properties are equal or better than those obtained by any other metachrome procedure

4 *Bottom-chrome or chrome mordant method* This method is used on fine woolens and worsteds when a maximum levelness of shade is of paramount importance The bottom-chroming operation tends to equalize the affinity of the wool fibers for dye and decreases or eliminates the fiber selectivity which causes heathery or skittery effcts

This method is used especially for certain types of alizarin colors, which can be combined only with already mordanted wool fibers This means that the wool is first mordanted by precipitating a metallic salt on the fibers, which forms an insoluble lake with the dye in the subsequent dyeing procedure With very few exceptions, the bottom-chrome method gives the poorest fastness to fulling

However, experiments have shown that the dye that bleeds during the fulling operation is generally unchromed color which was absorbed by the fiber during the dyeing operation but which did not combine with the chromium on the wool Improved fastness to fulling will be obtained if an addition of ½ to 1 per cent of bichromate is added to the exhausted dye bath. The dye bath should show a pH of 5 5 or lower when the bichromate is added

Mordanting is carried out chiefly with sodium bichromate and tartar or chromate of soda and tartar Alumina salts are used for the production of bright reds The most widely used chrome-mordanting process is as follows

The bath is set with 3 per cent bichromate and 2½ per cent tartar or

of these mordant colors it is extremely difficult to correct shades that are too dark or streaky For this reason it is important to start the dyeing operation at the proper pH so that the dye will exhaust slowly and be absorbed uniformly Microscopical studies have shown that the dye is absorbed first as the acid or unchromed form in metachrome, Calcomet, and bottom-chrome dyeings This allows the dye to redistribute itself and level as an acid color during the time the temperature is being raised to the boil When the boil is reached, chromation of the dye takes place more rapidly and there is less chance of leveling thereafter Once the insoluble chromium complex of the dye is formed, little if any leveling can take place

Uneven goods may be stripped in a hot soda bath, and treated with hydrosulfites or sulfoxylates As a rule, it is considered better practice to redye to a darker shade because the color may strip down unevenly and be difficult to cover up when redyed

As a general precaution it is wise to keep the shades on the light side and to use small amounts of level dyeing acid colors for matching When the shade is too light, the dyeing procedure has to be started over again with chrome colors as with undyed goods

Stripping of Acid and Chrome Colors

Stripping consists of the removal of colors from yarn or fabric by decolorizing the dye There are various stripping compounds on the market, which either through oxidizing or reducing action are able to destroy dyes The oxidizing agents have the disadvantage that they not only destroy the dye but actually reduce the tensile strength of the fabric by weakening the wool fiber The hydrosulfites, which are powerful reducing agents, have less tendering or weakening action and are generally adopted for stripping textile materials They can be used in an acid, neutral, or alkaline solution, making them suitable for all textile fibers For stripping wool, the hydrosulfites are chosen for working in an acid bath The general method used in stripping wool with hydrosulfites is as follows 2 to 5 per cent of formic acid is added to the freshly prepared bath, the goods are entered, and the temperature raised to approximately 120 degrees F Then 2 to 5 per cent hydrosulfite is dissolved and added immediately to the bath, and the temperature is rapidly raised to the boil and boiled for one-half hour The bath is dropped and the goods are thoroughly rinsed before redyeing Depending on the type of hydrosulfite used, the best stripping action is generally attained

below the boiling point Hydrosulfites are marketed by various firms under special trade names

Soluble sodium zinc formaldehyde sulfoxylate is also used because of its excellent stripping action The bath is set with 3 to 5 per cent of sulfoxylate and 2 to 4 per cent acetic (56%) The lot is raised to the boil and boiled for thirty to forty minutes When stripped, the wool is rinsed thoroughly in warm water, and then treated in a fresh bath with 1 to 2 per cent ammonia at 160 degrees F for twenty minutes This treatment reduces the affinity of the stripped wool for dye and makes it possible to redye tightly woven fabrics and obtain satisfactory penetration

Speck Dyeing

Pieces are speck dyed to cover burrs and shives, cellulose and other types of fibers which remain uncolored or lightly colored when wool pieces are dyed in an acid bath Speck dyeing is a makeshift process at best and should be avoided whenever possible The direct colors used for this purpose are selected because of their lack of affinity for wool The dyes are applied cold or warm (80 to 100 degrees F), and Glauber's or common salt is used to exhaust the color High temperatures are impractical for speck dyeing because the wool would absorb a considerable portion of the direct color and show a radical change in shade However, each additional 5 or 10 degrees in temperature that can be used will aid in the penetration and development of the speck dyes Despite the precautions which are generally taken, some of the direct dye adheres loosely to the wool and the fastness to crocking, water, and washing is reduced in proportion to the amount of unfixed dye remaining on the pieces After speck dyeing the pieces should be rinsed several times to remove as much loose dye as possible and dried as soon as possible to prevent migration (which may cause bronzing)

Dyeing with Vat Colors

In the dyeing methods heretofore discussed the dye baths are prepared with dyes that are soluble in water Vat dyeing, on the other hand, employs dyes that are generally insoluble in water The consequence is that the methods of dyeing are different in both their chemical aspect and actual procedure The dyes suitable for vat dyeing are coloring substances that are capable of being reduced to alkali-soluble leuco compounds and are fixed in this form upon the fiber They are then re-

formed by spontaneous oxidation in the open air into insoluble color pigments and thus produce the color on the fiber

Chemistry of vat dyes Chemically, the vat dyes may be divided into two groups the anthraquinone vat dyes and the indigoid vat dyes The anthraquinone vat dyes, owing to the strong alkaline nature of the dye bath, are generally not suitable for wool, although it is possible through the use of protective colloids to minimize damage to the wool fibers

Dyeings produced with vat dyes possess the best all around fastness and are recommended whenever maximum resistance to the various manufacturing processes and wearing is required as in Army or Navy uniforms In wool dyeing, two types of vats are employed (1) the hydrosulfite vat, (2) the warm fermentation vat

1 *The hydrosulfite vat* The hydrosulfite vat is the most popular because it is easily prepared and operated, preserves the quality of the wool, requires little room and steam, and gives a large production The oldest representative of this type of dyestuff is indigo, the blue color which sets the standard in light fastness

Since the vat dyes are insoluble in water, it becomes necessary to transform them with the help of caustic soda and hydrosulfite into a reduced leuco compound Up to 1920 this process had to be done by the dyer himself, but since then dye concerns have introduced vat colors in powder form, which are soluble in hot water In addition, there are various auxiliaries required for proper operation of the hydrosulfite vat, as follows·

Glue, which serves as a protective colloid to keep the dye in solution in the vat Alkyl naphthalene sodium sulfonates may be used in place of glue

Ammonia (25%) is used to keep the vat on the alkaline side

Hydrosulfite conc. (powder) is a powerful reducing agent which regulates the condition of the vat and prevents its oxidation

Sulfonated oil soaps or similar products serve in the dissolving of the vat dyes, when preparing stock vats The proper alkalinity of the bath is checked with phenolphthalein solution (5 .1000).

The stock vat is first prepared by dissolving the necessary dye in water at a suitable temperature, which may vary from 130 to 170 degrees (1 30), with the necessary amount of caustic soda and hydrosulfite. The process requires at least fifteen minutes at that temperature The vat dyes in soluble form are dissolved with boiling water to which 5 per cent glue and 5 per cent hydrosulfite conc (powder) on the weight of the dye have been added The solution obtained is allowed to stand for a short time before it is added to the dye bath The dye bath proper

is brought to a temperature of 120 to 170 degrees F. For 65 pounds of wool 550 to 660 gallons of vat liquor is needed To this liquor are added, in the order given

3% freshly dissolved glue
3% ammonia (25%)
2% hydrosulfite conc (powder)

These percentages are based on the weight of the goods At this point the bath is ready to receive the stock vat solution The liquor is then well stirred and should have the following characteristics (1) a clear transparent appearance with a light foamy film of oxidized dye on the surface, (2) a slightly reddish reaction when tested with phenolphthalein Into this healthy vat (as called by the dyer) the wool is entered dry or preferably wetted out and hydro-extracted, and worked for twenty to thirty minutes After it is taken out of the liquor, it is passed between squeeze rollers and dropped into boxes, where it is allowed to stand for ten to fifteen minutes to oxidize

When oxidation is completed, the wool is either rinsed or given a second dip for deep shades Thorough squeezing is essential after each dip The fastness to rubbing may be improved by dropping the wool into cold running water after the squeeze, if this is done the oxidation proceeds more slowly

To run the vat economically it should be kept going continuously, averaging about ten dips per day, the same vat liquor can be kept for about a week when thoroughly scoured wool or goods are used Before making an additional dip the vat has to be brought back into condition by adding the necessary quantities of ammonia and hydrosulfite to make the liquor once again transparent and slightly alkaline to phenolphthalein Additions of dye are made only after the vat is corrected Additions of glue are not necessary when working with a standing bath The vat liquor is not exhausted, and, therefore, the quantity of dye required to bring it to normal strength may be reduced in the following proportions

	Second Bath	*Third Bath*	*Fourth Bath*
For most indigo brands	30%	10%	10%
For all other vat dyes	15%	10%	——

Commencing with the third batch the dye quantity for replenishing remains practically stationary The shading of the color in vat dyeing is quite a simple matter The stock vat necessary for additions is diluted with vat liquor in a pail This diluted solution is then added to the vat liquor while working the goods After fifteen to twenty minutes the shade is matched again

To increase production vat colors can be dyed also in circulating machines in which the stock is stationary and the vat liquor is forced through the wool by means of a pump or propeller. In such machines about four times the quantity of wool may be dyed in the same volume of liquor as can be dyed in the open vat The general makeup of the bath is 1 per cent glue, 0 5 to 1 5 per cent ammonia (25%), and 1 5 per cent hydrosulfite conc. (powder) Otherwise, the working procedure is the same as in the open vat Special precaution has to be taken against entry of air into the circulating liquor, which causes oxidation and uneven dyeing The vat liquor is renewed more often because of the greater amount of material treated

For blacks and navys the best procedure, when using circulating machines) is to replace the ammonia right from the start with 1 to 4 per cent of ammonium sulfate Two dips of half an hour each are normally required to get the depth of the shade and good exhaustion of the liquor Cheap blacks may be obtained by using natural brown wool as a raw material and dyeing it with indigo

The warm fermentation vat Since the introduction of the hydrosulfite vat, shortly after the turn of the century, the fermentation method has been superseded almost entirely by the hydrosulfite procedure, because the latter is much easier to set and work besides yielding a much larger production The principle of the fermentation vat makes use of fermenting agents such as woad, madder, and wheat bran and syrup. In the presence of alkali such as soda and chalk these agents start the ferment due to the existence of fungi that liberate hydrogen. Thus a reduction of indigo is effected One to two days are required to bring the vat to proper condition so that actual dyeing can be started

Several dye concerns have developed a limited number of vat colors covering all the shades from yellow to blacks The best known are the Helindon dyes from the General Dyestuff Corporation Helindon dyes are separated into two groups the HN group and the HW group

The difference lies in the fact that the dyes of the HN group are dyed at a temperature from 120 to 130 degrees F , whereas the dyes in the HW group are dyed at 140 to 150 degrees F

Of special interest is the water in vat dyeing Contrary to all other dye groups, the HN group dyes are taken up much more readily from hard water than from soft water The best hardness is 20 to 30 grams per gallon When only soft water is available 2 to 4 per cent sulfate of ammonia may be added at the start For the HW group of dyes soft water is purposely hardened with 5 per cent calcium chloride (calcined) After air oxidation the dyes of the HW group are scoured in a fresh bath with 3 to 5 per cent acetic acid (28%) for complete de-

velopment The treatment is done by entering the goods in a bath at 100 degrees F, brought to the boil and boiled for five to ten minutes

Correction of vat dyeing In view of the excellent fastness properties, vat dyeings which are not level or are too dark are very difficult to rectify A partial stripping may be obtained in an alkali bath set with hydrosulfite Wool with tips strongly damaged by sunlight dyes unevenly with indigo because the staple ends remain nearly white To correct such wool the batch may be cross-dyed with 0 1 to 0 25 per cent of sulfone cyanine blue in an acetic acid bath

Continuous Indigo Dyeing

1 *Stock dyeing* A high production can be obtained in the continuous wool-stock dyeing machine (described previously in this chapter) The success of this or any other continuous dyeing is entirely dependent on the synchronized flow of both the material to be dyed and the dye liquor through the machine Any fluctuation in the flow of one or the other components is a direct cause for the failure of the bath.

The dye-liquor circulating system as seen in the flow diagram (Fig 19) includes provisions for circulation and replenishment of the liquors in the two dye bowls as well as the necessary tanks for the preparation and storage of the stock solution and the feed vat In the system referred to, in order to take care of a capacity of 550 pounds of dyed wool per hour, four tanks are utilized, one of which has a 400-gallon capacity and three others a 1000-gallon capacity The tanks are all interconnected and provided with pumping facilities so that the solutions may be

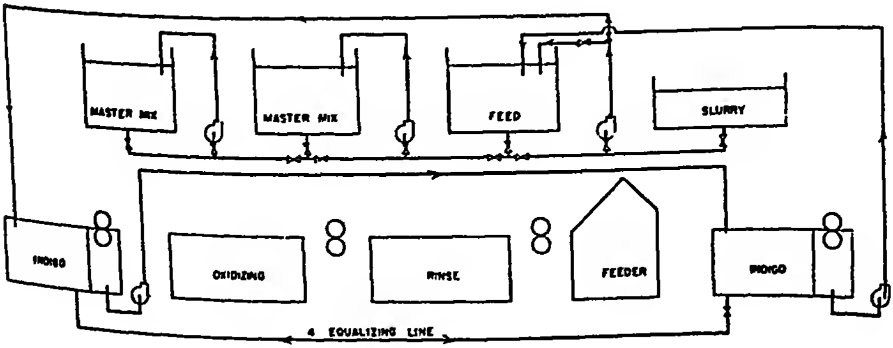


Fig. 19 Indigo liquor flow.

passed from any one tank into another. Each tank is equipped with hot and cold water inlets as well as with an internal steam-coil system, thermostatically controlled in order to maintain the correct vat-liquor temperatures The slurry tank is equipped with a large stirrer, required for slurrying the indigo paste into the mixing of the stock and feed baths Each of the circulation tanks is provided with an agitator, to avoid sedimentation of the indigo.

For continuous stock dyeing with indigo, the soda and hydrosulfite vat as worked out by William Wentz of the du Pont Company was found to be very satisfactory The depth of the shade as specified by the U S Navy Department for its 30-ounce kersey could be acquired by two dips of six minutes duration each

In the dye liquor the most favorable indigo concentration is 3 grams per liter dry basis or 15 grams of indigo (20%) paste The completely dyed fiber maintains an indigo content of 7 per cent of which 60 per cent is attained in the first dip and the remaining 40 per cent in the second dip

The efficiency of the bath and the duration of its effectiveness is entirely dependent on the control of the accumulation of the various chemicals which in turn are necessary for indigo dyeing The oxidation products of sodium hydrosulfite accumulate and build up continuously and upon reaching an equivalent of approximately 8 grams of oxygen per liter the effectiveness of the dye bath is terminated

The caustic soda and the sodium carbonate in reacting with the oxidation products of the hydrosulfite lead to the formation of sodium bicarbonate The entire reaction is a continuous cycle The total alkali builds up to approximately 20 grams per liter during a ninety-hour run with the coincident increase in the bicarbonate concentration Maintenance of a certain carbonate concentration is mandatory to effective operation

The preparatory procedures are as follows:

A Spring bath Fifteen hundred gallons of water are added to both dye bowls along with 600 gallons to the feed tank This is heated to 130 degrees F While the feed tank is coming to temperature the glue is slowly added The additions of soda ash, Alkanol B (a dispersing agent, sodium alkyl naphthalene sulfonate), and ammonia follow in this order When all temperatures are constant the hydrosulfite is added This prepared bath is now thoroughly circulated through the dyeing system

Glue	65 lb
Alkanol	60 lb
Soda ash	33 lb
Ammonia	220 lb
Hydrosulfite	22 lb

B Stock vat To the 400-gallon slurry tank which has sufficient water at 140 degrees F to permit the use of the agitator, the indigo (20%) paste is added, followed by the caustic soda This slurry is now brought to 400 gallons and 130 degrees F, and then the hydrosulfite is added Pumping this stock vat to the feed tank and thereby circulating it throughout the machine in the spring bath prepares the machine for dyeing After proper circulation, all pumps are stopped for fifteen to twenty minutes to ensure proper reduction

Indigo (20%) paste	1255 lb
Caustic soda	112 lb
Hydrosulfite	163 lb

C Master mix In the two remaining 1000-gallon tanks, replenishment baths are prepared The glue, Alkanol B, and soda ash are added to sufficient water at 130 degrees F to permit the use of the agitator Meanwhile the indigo (20%) paste has been added to the slurry tank with water at 130 degrees F and is agitated with approximately one-half of the caustic soda This slurry is pumped to the master-mix tank and made up to 1000 gallons at 130 degrees F, after which the remainder of the caustic soda and the required hydrosulfite are added Twenty-five gallons of this master mix are added to the feed tank every fifteen minutes It was ascertained that 5 pounds of additional hydrosulfite was required each fifteen minutes to compensate for indigo oxidized in the dye bath Introducing this into the master mix brought about precipitation of indigo-white Therefore, the additional hydrosulfite was slowly sprinkled into the feed tank after every feed

Glue	22 lb	Indigo (20%) paste	2550 lb
Alkanol B	45 lb	Caustic soda	225 lb
Soda ash	66 lb	Hydrosulfite	325 lb

These figures represent an average dyeing recipe for approximately 42 per cent depth of shade on wool

2 *Piece dyeing with indigo* The basic formula which covers the continuous-piece-dyeing process is as follows

The initial charge of the machine which, as stated before, holds 3000 gallons, is made up of three items the necessary volume of water, the spring, and the stock vat

The spring is made up as follows at 140 degrees F (in ounces per gallon)

0.21 Alkanol B	0 13 Soda ash
0.21 Animal glue	0 19 Hydrosulfite of soda
0 79 Ammonia (28%)	

The stock vat is prepared in one of the 500-gallon tanks on the following basis at 140 degrees F (in ounces per gallon)

27.2 Indigo (20%) paste
2 4 Caustic soda flakes
3.6 Hydrosulfite of soda

It is best to permit the stock vat to stand undisturbed for at least two hours or preferably overnight before using

After the spring is allowed to run into the indigo tank and is circulated, the stock vat is run in and circulated for at least one hour before the starting of the machine

The feed liquor is made up in the other 500-gallon tank as follows (in ounces per gallon)

13 74 Indigo (20%) paste
3 042 Caustic soda flakes
0 48 Soda ash
4 16 Hydrosulfite of soda

This 500 gallons will normally take care of about forty pieces of flannel, or about 3000 yards, and it is fed in continuously to keep the liquor constantly at a predetermined level in the tank

It has been the experience that once the proper equilibrium between the original bath and the feed has been reached to meet the required shade, little or no change has to be made during the run.

TABLE 3 DIFFERENCES IN BREAKING STRENGTH OF YARNS AND PIECES FOR 30-OUNCE KERSEY USING DIFFERENT BLENDS AND DYED BY DIFFERENT METHODS

Wool Blend · 64's	*25% Australian 25% Cape 50% 12 Mo Texas*			*100% Cape*		*100% 12-mo Texas*	
Dye Process	*Natural*	*100% Chrome*	*50% Algosol 50% Chrome*	*100% Chrome*	*100% Indigo*	*100% Indigo*	
Yarn 2 5 run							
Breaking strength	185	147	134	161	186	173	
Per cent	100	79 5	72 5	87	100 5	93 5	
Elongation .	29 7	20 8	19 2	19 8	27 1	32 2	
Per cent ..	100	70	64 5	66 5	91	108 5	
Breaking Strength in Piece							*Navy Specifications*
Warp ..	112	81	102	98	121	113	90
Per cent	100	72	91	87	108	101	
Filling ..	98	73	89	98	113	98	80
Per cent	100	74	91	100	115	100	

The interest in the United States in wool vat dyes has for years been mainly limited to indigo, the oldest of all vat dye colors The only military specifications calling for the use of indigo vat dyes are the ones issued by the U S Navy Department for the manufacture of the navy blue flannel, melton and kersey In Europe the military authorities of several countries, including Germany, for years have specified the use of vat dyes in the production of military cloth as a result of tests for their fastness properties, their influence on the quality of the wool, and the wearing properties of vat-dyed woolens

That indigo dyeing preserves the quality of the wool better than chrome dyes was proved by the results obtained at the Forstmann Woolen Company given in Table 3

Dyeing with Solubilized Vat Dyes

The solubilized vat dyes are a group of dyes marketed as Indigosol (Carbic Color and Chemical Company) and Algosol (General Dyestuff Corporation) They are readily soluble in water and are applied to animal fibers without vatting Chemically, they are sulfuric esters of leuco vat dyes Being derived from indigoid and anthraquinone vat dyes, they possess high fastness properties

The solubilized vat dyes are applied to wool from a weak acid bath and under these conditions generally have such a high affinity for the wool fiber that the dye bath can be completely exhausted The dyes are then developed or oxidized with sodium nitrate or bichromate and sulfuric acid similarly to the ordinary after-chrome colors For the various dyes, two processes are mainly used

Process 1 Indigosol O (the ester salt of indigo) and Indigosol OR are dyed by this process · the dye is dissolved by pouring hot water over it and the solution is poured into the dye bath The following are then added.

5 per cent Glauber's salt (calcined), 1 per cent Rongalite C, 3 to 8 per cent acetic acid (28%) for pale shades, i e , up to 5 per cent dye, 3 to 6 per cent formic acid (90%) for heavier shades.

The goods enter at 105 degrees F, are raised to boiling, and are boiled for half an hour The bath is then exhausted by adding 2 per cent sulfuric acid 96% (66° Be), boiling for three-quarters of an hour, and cooling to about 75 degrees F by running in fresh water The developing bath is set with 7 parts sulfuric acid 96% (168° Twaddle) per 1000 parts liquor For improving the fastness to rubbing 2 to 4 parts Indigosol Soap SP per 1000 parts liquor in the case of full shades are added

and run cold for ten minutes Then in the form of a dilute solution, the following are added

FOR	INDIGOSOL O	INDIGOSOL OR-
1% dye or less	0 4%	0 3% sodium nitrite
4% dye or less	0 8%	0 7% sodium nitrite
10% dye or less	1 6%	1 4% sodium nitrite
20% dye or less	2 7%	2 4% sodium nitrite

Then follow treatments with Indigosol O for one hour at 75 degrees F and with Indigosol OR for forty-five minutes at 120 degrees F after having raised the temperature gradually to these points Then follows a thorough rinsing, and if necessary a cold neutralization treatment with two parts soda ash per 1000, and a final rinse

Process 2 After the dye is dissolved by pouring hot water over it, it is added to the dye bath together with 5 per cent sulfate of ammonia The goods are entered at 105 degrees F and raised to a boil in one-half hour The dye bath is then exhausted by the addition of 1 to 10 per cent acetic acid (30%), boiling for one half to one hour and rinsing The developing bath is set with 1 to 3 per cent sulfocyanide of ammonia and 0 7 to 3 5 per cent bichrome and run for one quarter of an hour at 85° F Then 5 parts of sulfuric acid (96% or 66° Be) are added per 1000 parts of liquor, and allowed to remain for one half hour at 185 to 195° F The final operations are the same as above For shading, acid-dyeing shading dyestuffs are used as for chrome dyeings

To ensure that the dyeings will be fully developed, it is advisable with compound shades to use not less bichrome than the amount needed for the dyestuff which requires the most bichrome

At the present time, the chief application for solubilized vat dyes is in piece dyeing The 16-ounce bright scarlet kersey, used by the U S Navy for chevrons, is probably the only fabric outside of the indigo blues where vat colors are used on a large scale to meet the high fastness requirements The shade can be obtained by using 25 per cent Helindon Scarlet GG paste (color index 1228) and 0 75 per cent Ciba Red 3B double paste (color index 1212). In order to get the full brilliancy of these shades, the stock after careful rinsing and air oxidation is soured with 2 per cent acetic acid at 175 degrees F for one-half hour

The reason vat dyes for wool have not yet found wider adoption is due to the large range of wool dyes, especially the chrome dyes, which meet the normal fastness requirements of the various branches of wool dyeing and at the same time are much cheaper and easier to apply Their present use for mens' suitings is almost negligible but they are especially suited for effect strips in fine wool shirtings as their fastness to laundering and bleaching is outstanding With the increasing production of

washable woolens an increased demand for the use of these vat colors can be expected

SOME SOURCES OF FAULTY DYEING

Each different operation to which wool is subjected during its long journey from fleece to finished fabric is a potential source of trouble When materials from the dye house are unsatisfactory it is the dyer's responsibility not only to correct the faulty lots but also to take steps to prevent a recurrence The following sections have been prepared to assist a dyer to trace the causes of trouble

Tippy dyeing An ideal dyeing is one in which all dyes are distributed equally and uniformly among all of the fibers present However, this is rarely ever attained in practice and, instead, distinct differences in shade and depth of color are obtained on the same fiber or fleece These variations in affinity for dye are inherent in each fiber and are caused by unequal exposure to sunlight, weather, and other agencies while the wool is growing on the sheep Such differences in affinity for dyes result in what is called "tippy dyeing"[3]

Tippy dyeing occurs in several forms, the first and most serious being those dyeings in which the tips of the fibers are heavily dyed, while the body sections remain undyed or are only lightly dyed (Fig 20) A second variation is obtained where two or more contrasting colors are used to produce a shade that results in pronounced variations in hue and color value between the tips and body portion A third and less troublesome effect is caused by the tips remaining undyed or lightly dyed, while the body portions are heavily dyed (Fig 21) Some of

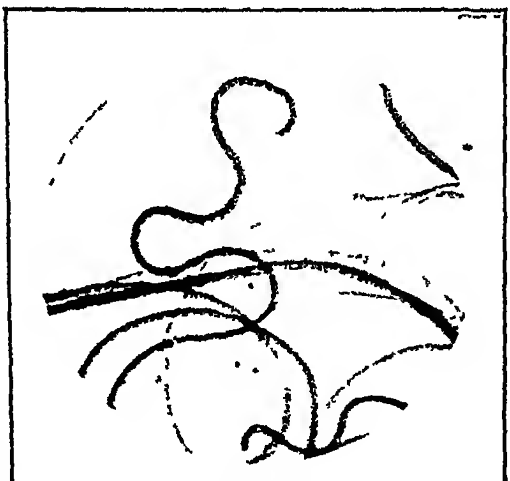


Fig 20 Tips dark, dyed with chrome brown SWN

[3] Race, E., Rowe, F M, Speakman, J B, and Vickerstaff, T "Unlevel Dyeing of Wool with Acid and Chrome Dyes," *J Soc Dyers and Colourists, 51, pp 141-*[illegible] (April 1938)

these extreme contrasts are reduced when the stock is carded and combed; but such operations cannot entirely eliminate these defects and therefore skittery, frosty, or heathery effects are obtained which result in weaker shades Tippy dyeing has long been recognized as a major problem and many attempts have been made to overcome this defect

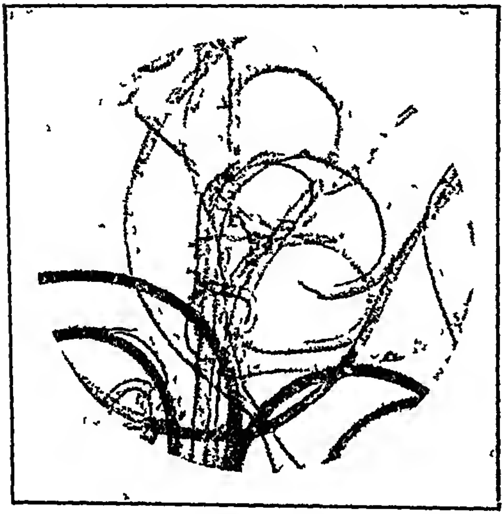


Fig 21 Tips light, dyed with indigo

In an extensive study of this problem made in 1946 by the New York Section of the American Association of Textile Chemists and Colorists it was found that tippiness can be minimized and even eliminated by the careful selection of the dyes and by the use of certain leveling agents [4]

Scouring. Scouring plays a very important part in the production of satisfactory work Soaps generally cause more trouble than the sulfated alcohols Calcium and magnesium salts react with ordinary soaps, forming insoluble calcium and magnesium soaps These metal soaps attach themselves to the wool and are difficult to remove. When pieces containing these insoluble materials are dyed they may cause the finished piece to appear cloudy and uneven The addition of sodium tetraphosphate to the scour and the rinse baths will help to prevent trouble caused by hard water Heavily dyed blotches and spots may be caused by splashing undyed skeins or fabrics with hot soap or alkali solutions

Wetting out Yarns and pieces that have been scoured and dried should be wet out in a bath containing a wetting agent such as Deceresol or sulfonated castor oil at 160 degrees F for twenty to thirty minutes prior to dyeing This bath may be used for dyeing so that further wetting out can take place as the temperature is raised to the boil Incomplete wetting can cause light areas in dyed pieces or skeins Microscopical

[4] The Tippy Dyeing of Wool and Its Control, *American Dyestuff Reporter*, 54, pp 486-506 (Nov 1947).

studies have shown that the dye is deposited first on the outer parts of the fibers and then penetrates the fiber when the critical absorption temperature is reached. Parts of the wool not wet out will resist the deposition of color during the early stages of dyeing and may remain weaker in shade throughout the dyeing operation. This is especially true of colors that level poorly or not at all

Stripping. Stripped wool generally has increased affinity for dyes of all kinds and therefore should be dyed with smaller quantities of exhausting agents When dyeing with nonleveling colors, special precautions should be taken because stripped wool absorbs dyes rapidly and fixation takes place at lower temperatures than it does with untreated wool, therefore, the color must be removed from the bath more slowly at a uniform rate Tightly woven fabrics are especially difficult to penetrate after stripping and therefore additional precautions must be taken when dyeing such materials

Machine oil and spinning oil. Greases and oils are a constant source of trouble to the dyer and must be removed before dyeing. These materials usually cause lightly dyed or resisted areas in dyes pieces. The dye bath cannot come in contact with the wool when it is covered with oil and therefore the fibers often remain undyed Dry cleaning the pieces before dyeing has greatly reduced the imperfections caused by oils and greases

Boiler compounds Most mills use boiler compounds to prevent the formation of scale Little trouble is experienced unless these materials contain free caustic soda or soda ash, caustic soda is especially troublesome as it is liable to be entrained in the steam and carried into the dye bath When this occurs, the amount of alkali in the bath increases with time and gradually neutralizes the acids used for dyeing and retards the exhaustion of the color from the bath When dye baths become difficult to exhaust by standard procedures, the steam condensate should be tested for alkalies If it is found to be strongly alkaline the boiler should be blown down and a caustic-free compound adopted

Lime in pulled wools Pulled wools are often loaded with lime and can easily cause trouble for the dyer Heavily limed wools remain undyed because the outer parts of the fibers are coated with the insoluble compound and the dye bath cannot reach the fibers A pretreatment with hydrochloric acid will often correct this condition by dissolving the lime forming soluble calcium chloride Rinsing will remove the calcium compound and make it possible for the wool to absorb the dye.

Sun-bleached yarns and fabrics When wool in any form is exposed

to light either outdoors or behind window glass, wool is changed chemically and its affinity for dye is altered, depending upon the dyes used (See the previous section on tippy dyeing) The sun-bleached areas may show up either as a light streak or a heavier streak because certain dyes have greater affinity for the light-affected portions than they do the unaffected Conversely, other dyes have very little affinity for sun-bleached wool and considerable affinity for the unbleached portion

When the ends of undyed pieces are exposed to light and then dyed a streak of lighter shade may be seen throughout the length of the dyed piece This has been traced back to the effect of daylight upon the wool fibers Redyeing to a heavier shade is the best way to overcome this condition and it is advisable to use dyes that color exposed and unexposed wool about the same

When scoured but undyed skeins or pieces are to be stored prior to dyeing, they should be protected from light by covering with cotton sheeting or encasing each roll or bundle in burlap or colored cellophane

Mixed stocks When fabrics are made from yarns containing different stocks barré effects often show up after the pieces have been dyed These are entirely different in appearance from unevenness caused by dyeing because the lines occur with regularity and follow the direction of the warp or the filling It is practically impossible to select dyes that will completely eliminate this fault in dyeing. Stripping with soluble sulfoxylate either before or after dyeing will minimize this effect and make it possible to produce a more solid shade

Effects of faulty steaming Single yarns are sometimes steamed to set the twist If the steam is applied unevenly those areas subject to excessive steaming will have greater affinity for some dyes than will the partially steamed areas The steaming operation increases the affinity of the fiber for dye and therefore with colors such as the Sulfone Cyanine Blues, steamed wool will dye light and dark, resulting in a mottled effect when dyed in the yarn or pieces Unfortunately, redyeing to the same shade does not overcome this difficulty Therefore, when the fault can be traced to steaming, the pieces should be redyed black

Carbonizing and neutralizing Carbonizing and neutralizing faults are responsible for a large number of the difficulties encountered by a dyer when using acid-sensitive dyes Recent experiments have shown that it is extremely difficult to neutralize wool completely after it has been carbonized Unless the neutralization is uniform and complete, pieces dyed with acid-sensitive dyes may come out uneven This is because many neutralizing baths cause the pieces to be completely neutralized on the outside but incompletely neutralized on the inside of the

fabric As the temperature of the dye bath is raised to the boil, the acid from within the fabric is released and neutralizes the alkaline parts When this occurs, the pieces become acid and the dye exhausts rapidly on the outer parts of the pieces Blotches and other unevenness have also been traced to careless or improper neutralizing after carbonizing. However, there are metalized dyes such as Calcofasts, Neolans, and Palatines that give excellent results when applied to unneutralized carbonized stocks

Feeding of dyes Adding dyes to a dye bath for the purpose of matching the lot to a standard shade requires a high degree of skill and care. The leveling acid colors may be added to a boiling dye bath without great risk because they level well and each feed registers and changes the shade If too much of one color is added and the shade is made too full or contains an excess of one of the dyes, it is not serious because the unwanted dye can generally be removed by adding Glauber's salt or by running the bath down half way.

With milling colors or other acid-sensitive dyes, feeding becomes a real problem Practical experience has shown that these sensitive dyes can be added in small quantities to correct a shade if certain precautions are taken The pH of the dye bath at the time of feeding is of paramount importance The bath must be close to the neutral point or only slightly acid if good results are to be obtained Microscopical studies have shown that dyes exhaust rapidly at high temperatures, and are deposited first on the outer parts of the fibers regardless of temperature With time, the dye penetrates the fiber and fixation takes place Therefore, sufficient time must be allowed after feeding for penetration and leveling to take place

There are times when the nature of the dye will make it necessary to add the shade-correcting colors in a fresh bath at a low temperature and raise slowly to the boil Boiling should be continued for thirty to forty-five minutes to ensure levelness and development of shade

Artificial light Shades that change radically in different lights often contain orange, green, or violet When an accurate match is required the standard should be examined in both daylight and in artificial light to determine the extent and nature of the change

Matching shades Examination of a shade in ultraviolet light often gives a clue to the nature of the dyes used to produce the shade Certain shades dyed with acid colors may have a peculiar changeable cast that is extremely difficult to match in all lights If the shade fluoresces in ultraviolet light, one or more of the dyes used in the combination may

have been an acid or basic Rhodamine, Acid Eosine, Brilliant Sulfo Flavine, Calcomine Fluorescent Violet 2G, or others that do not fluoresce to the same degree Additional information as to the nature of the dyes may be obtained by boiling the dyed sample in water containing ammonia The solution containing the dyes that are removed from the sample should be concentrated by evaporation The end of a strip of filter paper is placed in the solution, and the dyes will separate because of differences in their water solubility. Examination under ultraviolet radiation will show which of the dyes is fluorescent

A more accurate method is to pass the unknown dye solution through a chromatographic column that separates the dyes, forming definite rings of different colors Examination of the column in ultraviolet rays will make it possible to detect the dye which causes the radical color changes in artificial light and daylight

Excessive crocking Materials that crock excessively do so because some of the dye has remained on the outer parts of the material When the dye has been absorbed within the fibers, excessive crocking disappears Crocking can be reduced by controlling the rate of exhaustion and dye penetration Sufficient time at the boil is also essential for best results If a fast-to-washing color crocks excessively a light soap scour will often remove the loose color and improve the fastness

Incomplete airing before matching Incomplete airing before matching to a standard shade may be responsible for poor matches Colors applied to wool exhibit definite color changes when the wool is dehydrated or when it contains more than a normal amount of moisture For example, Wool Green S is almost a reddish blue when bone dry, but is much greener when the wool contains a normal amount of moisture, and if the wool is damp, the shade is considerably more yellow

DYEING WOOL MIXTURES

Of the various fibers that the dyer is called upon to bring to greater perfection, sheep's wool plays by far the largest part A less extensive use is made of the fleeces of other animals, the most important of which are (1) mohair, obtained from the Angora goat, (2) cashmere, derived from a species of goat living in central Asia, (3) camel's hair, (4) alpaca, vicuña, and other hairs of the llama family, (4) cow, calf, and horse hair, used occasionally for certain goods, and (6) rabbit hair, largely employed in the manufacture of hats

Although the chemical character of the various kinds of wool and

hair is pretty much alike, there are nevertheless slight differences in their behavior in dyeing, so that the affinity of the dyes for the various fibers differs more or less As a general rule, the finer the fiber, the more dye it will absorb in producing a given shade, since under equal conditions *the finer fiber, in presenting a larger surface in proportion to the bulk, takes up more dye than a coarser fiber*. Hence, it follows that it is advisable to use materials of as uniform a fiber as possible, especially for goods to be piece-dyed, and also that difficulties will arise in employing wools from different kinds of animals simultaneously, unless it be intended to produce a contrast between the various fibers

Generally speaking, the process of dyeing sheep's wool applies to all other animal fibers, apart from slight variations which their structure necessitates for obtaining greater or smaller affinity for the dyes Therefore, it is not necessary to discuss the mode of dyeing of these special fibers, since their treatment can be easily derived from what is stated about general dyeing of wool

Union Dyeing

The coloring of unions is one of the most difficult of all dyeing operations, and considerable skill on the part of the colorist is required to achieve success in this field Union fabrics are prepared by combining two or more different textile fibers to produce the desired result Unions are produced for one of two main reasons, either for economy or for special effects The material may contain several fibers such as virgin wool, reprocessed wool, or reused wool, mixed with cotton, rayon, acetate, nylon, silk, or synthetic casein fibers The greater number of different fibers used in a fabric, the greater the problems of dyeing

If the material contains wool, best results are obtained by carefully selecting the dyes and by a proper balance between time, temperature, and exhausting agents The affinity of normal wool for dye increases with a rise in temperature and a lowering of the pH of the dye bath If a boiling temperature is maintained for a long time, the shade on the wool will increase in depth at the expense of the cotton or rayon When this occurs, the bath should be cooled rapidly and direct dyes added to fill up the shade on the cotton or rayon

Shades which have turned out too dark are best given a short boil with a ten per cent Glauber's salt bath When the desired result is not obtained 1/4 to 1/2 per cent of soda ash might be added, but the use of protective colloids is necessary to avoid alkali damage To prevent the wool from absorbing certain cotton dyes, special retarding agents have

been developed For example, modified sulfur containing phenol condensates produces very good results.

Aralac absorbs dye rapidly at low temperatures in the early stages of the dyeing operation However, as time and temperature are increased, wool can absorb acid and dye from the Aralac and build up rapidly in dye concentration To prevent this in dyeing wool and Aralac mixtures, the dye bath should be buffered and the pH controlled by an addition of disodium phosphate or other buffering compound.

Wool and Silk Mixtures

Silk is ordinarily used in wool and worsted yarns and fabrics to obtain stripes, as in men's wear fabrics, or to create light-weight fabrics such as silk cashmere Silk noils and tussah silks are used occasionally in woolen fabrics Such mixtures occur most frequently in woven or knitted piece goods Silk is an animal fiber and therefore closely related to wool Hence, most of the wool colors such as acid and mordant colors are also utilized in the dyeing of silk

The dyeing procedure varies according to whether solid or two-color effects are wanted, in other words, either to dye the silk the same shade as the wool, or to have the silk undyed or cross-dyed, if the silk is already colored

1 *Dyeing silk and wool the same shade* The best results are obtained by dyeing with acid colors in one bath The general procedure is as follows The dye bath is set with 5 per cent Glauber's salt (calcined) and 4 to 6 per cent sulfuric acid (66° Bé) The goods are entered at 100 degrees F and raised to the boil in about half an hour and dyed to shade just below the boil By severe boiling with reduced quantities of acid, the wool dyes deeper than the silk At temperatures between 180 to 200 degrees F and with a higher quantity of acid, the silk absorbs more dye For deep shades, like dark browns and marine blues, where silk is difficult to match with wool, it becomes advantageous to use a strong acetic acid bath (10-15 per cent), the bath is started with half of the necessary quantity of dye and after exhaustion the remaining dye is added during cooling to bring the silk to the same shade as the wool

2 *Dyeing silk and wool, leaving silk white* To accomplish this, dyes have to be selected that do not or only slightly stain the silk The normal procedure is to dye the wool first with acid or chrome colors as described before The dyeing must be done at a boil Should the silk be slightly stained, it is cleared up in a fresh bath consisting of 1 to 2

pounds hydrosulfite per 100 gallons of liquor at about 90 degrees F. Even better results are obtained with the addition of Setamol W S of General Dyestuff Corporation, after the boiling has proceeded for one-half to one hour Two to ten per cent of Setamol is recommended, depending on the amount of silk staining. An additional boil of at least a half hour is necessary The best effect is obtained by the use of acetic or formic acid at a high temperature It is practical to dye wool fabrics with white silk effects intended for dress goods with acid colors, whereas for men's wear fabrics chrome colors are chiefly employed

Wool and Vegetable Fiber Mixtures

Most of the fabrics in this group constitute the "unions," containing wool and cotton in various proportions already mixed in the raw stock, twisted-in yarns, cotton warp and wool filling, or vice versa The preparatory processes of the various types of unions before dyeing vary according to their makeup They are carried out in a way similar to all wool goods

Cotton being a vegetable fiber, in most instances requires an entirely different class of dye, as well as a different dyeing procedure Similar to wool and silk mixtures, the "unions" may be dyed in *solid* shades, dyeing the wool and cotton simultaneously The second condition is to dye the wool and leave the cotton white and finally to dye both wool and cotton to different shades

Dyeing wool and cotton the same shade The most common method is based on the fact that certain groups of dyes have an affinity for wool and cotton from a boiling Glauber's salt bath However, the affinity of the individual dye varies widely, some dyeing wool and cotton uniformly, others dyeing either the wool or the cotton more deeply Consequently, the dye manufacturers divide their colors into these various groups As a rule the wool dyes deeper at the boil, whereas the cotton dyes better at 180 to 200 degrees F By regulating the temperature, it becomes possible to force the dye either onto the wool or onto the cotton at will The procedure for pale shades is as follows

The bath is set at the ratio of 1 to 35 with 8 to 12 per cent Glauber's salt (calcined) on the weight of the goods, for deep shades the liquor ratio is 1 to 25 with 20 to 25 per cent of Glauber's salt (calcined) The dye bath is not exhausted and the dyeing is continued in the standing bath for economic reasons The quantity of dye necessary to renew the bath is ¼ to ⅕ of the initial quantity used, with about one-fifth of the original quantity of Glauber's salt The dyeing commences at 120 to 140 degrees F, is raised to a boil and boiled from one-half to three-quarters of an

hour until the wool has reached its proper shade To ensure that the cotton is sufficiently covered, the dyeing is continued with the steam turned off from a half to one hour Considerable deviation of both fibers may be corrected with the dyes enumerated

Dyeing the wool and leaving cotton white. In this process mostly acid colors may be used and applied in the same manner as described under acid colors To prevent any unnecessary weakening of the cotton, formic or acetic acid is used

Wool and Rayon Mixtures

With the introduction of "wool-like" rayon staple fiber, this type of mixture has gained considerable importance There are three kinds of rayon of importance to the wool industry (1) viscose rayon, (2) cuprammonium rayon, (3) acetate rayon

Viscose and cuprammonium rayon are in the final state composed of pure cellulose and therefore their dyeing properties are closely related to each other as well as to cotton The acetate rayon, however, is quite different in its dyeing properties, because the final product is a cellulose acetic ester requiring special dyes and procedures

The wool dyer may have to deal with rayon in these various forms (1) loose staple fiber, (2) rayon waste, (3) yarn mixtures, (4) continuous filament rayon yarn, or (5) a mixture of these in piece goods.

When treating acetate and wool mixtures, temperatures exceeding 175 degrees should be strictly avoided, because the luster is impaired and saponification sets in All rayons are very delicate in wet condition as they lose from 40 to 50 per cent of their strength, therefore, particular care must be exercised in handling

1 *Dyeing viscose and blends of viscose and wool* According to L Walmsley[5], the following are the methods in general practice for the processing of viscose and blends of viscose and wool

A Raw stock dyeing In order to dye rayon raw stock successfully, it should be remembered that rayon swells when wet, and packs very hard The only successful method is by the use of pressure machines, of which there are any number The ones using the greatest amount of pressure usually give the best results It is well never to overload the machine, and if the machine is one in which the flow is horizontal rather than vertical, to use a larger core than is customary, thus having a thin-

[5] Walmsley, L, American Viscose Corporation

ner wall to penetrate than would otherwise be the case The expansion tank should be sufficiently large to carry the liquor necessary to run the machines This is not the case in some makes, which precludes the use of certain types of dyeings, notably reduced vat

The best stock-dyeing machines are the ones that embody the use of stainless-steel shelves, separating the stock into several layers so that the dye can pass from one layer to the other rather than having to penetrate a single large mass

The following methods of dyeing have been done successfully on viscose staple fibers.

(a) To dye direct colors, the method used is to wet the goods out with a synthetic detergent, approximately 1 per cent on weight of goods, for about ten minutes Add the dye at the boil for fifteen minutes, add common salt as the formula calls for, in about four equal parts Boil ten minutes and sample; if additions have to be made, it is desirable to drop the bath to 160 degrees F. and add the dye, raise to boil, and add more salt. To a large extent this prevents unevenness As a general rule, however, additions are not necessary as allowances for the shade can be made on the succeeding batches, and after about three batches the shade should be established.

(b) Sulfur colors are dyed in the following manner: the stock is wet out in boiling water to which has been added a suitable detergent The previously dissolved dye is then added, but care must of course be taken that the dye is in solution It is well to add a slight excess of sodium sulfide If the dye is not properly in solution, it will adhere to the fiber and in subsequent operation will come off on the machinery. Further, it is not possible completely to re-reduce the dye and no matter how carefully it is washed, it is not possible for it to be removed, as the mass acts as a filter After boiling for fifteen to twenty minutes, salt is added to the required amount in 4 equal parts at five minute intervals. Dyeing is continued for another thirty minutes and a sample taken. The question of making additions is as outlined under direct dyeings (paragraph *a*), all baths should be cooled and brought back to boil or unlevel results will surely follow. The bath is dropped and given a cold water rinse and then the necessary oxidizing agent After oxidizing for about twenty minutes, it is dropped and given a boiling soap or synthetic detergent if the water is hard Great care must be taken that soft water is used or, if not, that a softener such as Calgon is used Otherwise, lime salts will be formed which are very difficult to remove

(*c*) Diazotized and developed colors are dyed in the manner of directs and given the diazotizing and developing treatment With raw

stock an excess of the developing bath is desirable, about one-third more; otherwise, an uneven developing takes place

(*d*) To apply vat dyes, the pigment method is the most successful The material is wet out in about 4 per cent synthetic detergent at 160 degrees F Run ten to fifteen minutes, add the pigment in 4 to 5 equal portions (five minutes each) and add the caustic and hydro (about 1 cc for 100 cc. of 40 per cent caustic and 8 per cent hydro on weight of goods). Continue twenty minutes and drop Rinse in cold water for five minutes Oxidize with sodium perborate and soap at the boil The reduced method is used to some extent but it has not been found to give an any more even dyeing, but does has the disadvantage that it is much more cumbersome to apply and opportunities for mistakes on the part of the operator are much greater. The advantages of the reduced method are the greater exhaustion of the dye bath and subsequent better money value, but when weighed against the greater risk of uneven lots and badly dyed batches, the advantage seems to lie with the pigment method Further, if the reduced method is used, a much larger expansion tank than usual is necessary in order properly to prepare the bath Indigosol dyes are not recommended When prolonged developing may be necessary, severe tendering of the stock will result

(*e*) Naphthols are applied in the usual manner, and the following precautions should be taken to ensure best results The naphthols should be in complete solution, otherwise, badly crocking goods will result The coupling bath should contain a good dispersing agent such as Diazopon A, which causes the unfixed color to become so finely dispersed that it forms a colloidal solution and can be readily rinsed with resultant improvement in fastness to rubbing.

B Top dyeing The procedures employed for the dyeing of raw stock also apply to top dyeing and the same precautions should be observed The system that dyes rayon top most successfully is the Abbott system The advantage of this system over others is that it embodies the use of a large core around which is wound the rayon top to approximately 1½ to 2 inches in thickness, depending upon the denier, the finer denier size having the smaller wall thickness This gives a greater velocity of flow than other types at low pressure, and results in perfectly level dyed top, which offers a minimum loss of tensile strength The drying of the top by the blower system is also very satisfactory, as there is no movement of the fiber, and consequently no entanglement, which results in satisfactory gilling. No recombing is necessary.

One point should be noted here, and that is that rayon top, when made, should contain approximately 1 to 1½ per cent of oil, the oil should remain in the top throughout the dyeing operation. If the oil is removed and the top is without oil after drying, it will pack very hard and will not gill at all, or if it gills, it will do so with difficulty and will contain a sufficient number of slubs to require recombing.

The drying time of rayon top is approximately five hours compared with two and a half hours for wool. The amount of rayon per spool is approximately 18 pounds, against 30 pounds of wool.

The dyeing of blended fiber in the yarn or piece is, of course, a matter in which several fibers must be considered at once, and the use of certain classes of dye are objectionable because of their effect on other fibers contained in the blend. Mainly for this reason, the bulk of fabrics or yarn containing woolen and rayon blends are for the most part dyed with direct colors and neutral-dyeing woolen colors, employed to dye the wool. It is possible to choose the dyes so as to obtain a fairly good fastness to light, but washing and perspiration fastness leave much to be desired. Darker shades can be obtained that are fairly satisfactory to light, washing, and perspiration. This is accomplished by means of diazotizing and developing and the choosing of neutral-dyeing wool colors that will withstand the diazotizing treatment.

A considerable amount of success has been attained by the application of vats and naphthols to yarns and piece goods, and it is quite possible to obtain good unions on wool and viscose employing these classes of dyes. This, of course, represents the ideal situation, and an entirely new field is open to blended fabrics when the use of vats and naphthols becomes general.

A great many fabrics of viscose and wool blends are today being dyed with vat colors, particularly in the sports' shirting and slacks fabric fields, and vat dyes are being employed on tropical worsted blended materials intended for summer wear. In some measure, these are dyed continuously.

In piece-dyed fabrics, where viscose is used as a white effect, a selection of suitable acid dyes is necessary to prevent staining of the viscose. Organic acids should be given preference as dyeing agents.

In dyeing various batches of rayons, there may be differences in the affinity between the different batches even of the same manufacture. Naturally these differences are considerably smaller, as they occur between the various types of wool. Rayons behave similarly to wool in that the finer rayons will dye much lighter than the coarse denier rayons. For example, a 2½-denier rayon will dye a shade only half as strong as a 16-denier staple.

2 *Dyeing wool and acetate mixtures* Acetate yarns and staple fiber, due to their chemical composition, require a careful selection of dyes in order to obtain satisfactory dyeing in mixed fabrics They are: Acele and Celanthrene by duPont, Artisil by Sandoz; Calcone by Calco Chemical; Cellitonm, Cellitazol, and Celliton Fast by General Dye Corp, Cibacet colors by Ciba, Nacelon by National Aniline & Chemical Co. and S R A colors by American Aniline Products Some of the best acetate dyes are produced by the Tennessee Eastman Corporation

In dyeing such fabrics it must be borne in mind that acetate rayon is very susceptible to alkali and temperatures above 185 degrees F It is therefore important that no soda be added to the washing or the dye bath and that the dyeing and subsequent drying be carried on at temperatures not exceeding 185 degrees F The preliminary washing can be carried out with the addition of neutral soap and ½ to ¾ pint ammonia (25%) per hundred gallons at a temperature not exceeding 105 degrees F

In mixed fabrics composed of acetate and wool the acetate is usually added as an effect fiber to piece-dyed goods and, therefore, the main problem the dyer will be confronted with is

Acetate to remain white, wool to be dyed The dyes suitable for this purpose are found chiefly among the acid dyes Some of them leave acetate very clear The dyeing procedure is simple. The goods are dyed for one hour at 185 degrees F (at the most) with 10 per cent Glauber's salt (calcined) and 2 to 4 per cent formic acid (90%)

As all acetate dyes stain wool more or less, it is not possible to dye the acetate and leave the wool white Acetate and wool may be dyed in two different colors This may be accomplished by using the acetate colors which leave the wool fairly clean in combination with regular acid dyes By adding retarding agents the clearness of the two shades may be considerably improved

When acetate rayon and wool has to be dyed a solid shade, the procedure is similar to that followed for producing different colors, with the exception that the selection of the dye is much easier This may be accomplished in one bath process

3 *Dyeing mixed fabrics composed of acetate, vegetable fibers (cotton or viscose), and wool* Such fabrics are very seldom produced in the woolen and worsted trade Depending on the effect to be produced (leaving one fiber white and dyeing the other, or dyeing each fiber in the mixture a different shade), a careful selection of suitable dyes has to be made as discussed under the various mixtures

4 *Dyeing shoddy containing cotton and rayon* Such mixtures are used extensively in producing very cheap fabrics, especially black, dark blue, brown, green, and olive shades When the goods are not subjected to severe milling, they may be dyed by the one-bath process as described under "*Dyeing wool and cotton the same shade*" For dyeing where relatively good fastness to fulling is necessary, the dyeing has to be after-treated with metallic salts such as chromium or copper salts with formaldehyde Special groups of dyes are recommended by the dye concerns

Finishing After Dyeing

After dyeing, there is usually a finish added to facilitate further operations such as carding

On goods to be run on the woolen system, an amount equal to about 5 per cent of sulfonated olive or peanut oil on weight of goods is added, which will leave the raw stock in a well-lubricated condition after drying Raw stock for carpets, of course, does not receive this oiling as it tends to pick up dirt and, therefore, would be unsatisfactory for the carpet trade These goods are processed without finish

Raw stock for the cotton system also receives a finish bath This is very little and is of a dry type such as a cationic softener or a wax There should be sufficient softener or wax to allow the cloth to run through the cards without slipping Too much will cause a clogging of the main cylinder and will result in excessive cleaning Too little will cause the fabric not to card well and will give an uneven web

Similarly, wool for the cotton system should not contain more than 2 per cent of oil, otherwise, difficulty will be encountered during the carding operation

BLEACHING WOOL

The wool fiber in its natural state always contains some pigment matter Even the best grades of the so-called white wool have a slight yellowish tint In order to produce a clear white color, it is necessary to remove these coloring matters either by tinting or bleaching

In brown and black wools the pigment matter is considerable; however the amount of these colored wools is small compared with the white wools and therefore they are seldom, if ever, bleached

To bleach wool by the tinting process means to neutralize the yellow cast of the natural wool by dyeing the fibers with a delicate tint of blue or violet It is therefore not a removal or a destruction of the natural

pigment, but simply a change of the yellow tint to a gray. Gray, being less perceptible to the eye, causes the wool to appear white The dyes suitable for the tinting of wool are the blues with a slight violet tone, such as the acid violets, which are applied in a slightly acid bath The actual amount of color required is very small and care must be exercised to avoid overtinting, or overbluing the wool to a strong bluish tone Wool bleached in this manner does not possess a clear white color as when the natural pigment is actually destroyed Destruction of pigments can be accomplished either by reduction or oxidation

The two main bleaching processes that are used are the sulfur dioxide bleach and the hydrogen bleach The former is the older and the latter is the more permanent and generally the more satisfactory A serious disadvantage connected with the sulfur dioxide bleach is that the wool retains the chemical very tenaciously with the result that the color of dyed material woven with the bleached may become affected on storage Also, the color of dyed material placed in contact with bleached material may be affected on storage

Sulfur Dioxide Bleach

The material may be either stoved, i e, treated with gaseous sulfur dioxide, or it may be treated in an acidified solution of sodium bisulfite In the first method the scoured hanks or pieces, if dry, are wetted out in a weak soap bath, hydro-extracted, and then submitted to the stoving process Stoving involves simply the exposure to the fumes of burning sulfur for six to eight hours or overnight The sulfur stove is constructed of stone or brick and should not contain any metal It is fitted with wooden rods or rollers for yarn and piece goods, respectively Pieces are passed in slowly and continuously at full width through a narrow slit from which they later emerge About 6 pounds of the sulfur per 100 pounds of material is ignited, the doors are closed, and the sulfur burns itself out in the stove The fumes are blown out and the material is very thoroughly rinsed in water, and then finally blued by the addition of small quantities of acid violet or indigo extract to the last rinsing water

Tops, packed yarn cops, and cheeses may be bleached with sulfurous acid derived from the liquid, anhydrous product obtainable in steel cylinders A lead-lined iron vessel, which can be air-evacuated and is connected with the steel cylinders by a lead pipe, is used The vessel is also fitted with a vacuum and pressure gauge, air valve, and a leaden steam pipe in the floor

In the second method a cold bath (500 gallons) is made up with

about 2½ gallons sodium bisulfite (10° Twaddle, 37° Bé), and 4 pounds sulfuric acid per 100 pounds of material The yarn is thoroughly saturated and then steeped for two to three hours Good ventilation is necessary as large quantities of sulfur dioxide are evolved After rinsing, the materials are blued by the addition of acid violet or indigo extract in the last rinsing water

Hydrogen Peroxide Bleach

A cold bath containing per 100 gallons, 10 to 12 gallons hydrogen peroxide 3 per cent by weight (12 vols) or 1 gallon hydrogen peroxide 30 per cent by weight (100 vols.), is prepared and made slightly alkaline (pH 8-9) with sodium silicate or ammonia In place of hydrogen peroxide, sodium peroxide may be used, in which case a cold bath is made up with 12 to 13 pounds sulfuric acid per 100 gallons and then 10 pounds sodium peroxide is slowly stirred in At this stage the bath, now slightly acid, is made alkaline by the addition of a small quantity of sodium silicate The well-scoured material is saturated and then steeped overnight for some twelve hours

Yarns and tops are often bleached in machines The latter, like the open bleaching vessels, must be of wood, of stone, or of earthenware Connecting pipes are of clay or earthenware, the pumps for circulating the liquor of earthenware or porcelain, and the heating pipes should be of lead and detachable Of late, stainless steel is also used for the heating coils and pump driver

It is advantageous to use an apparatus for bleaching that is provided with a special liquor tank fitted with a stirring arrangement, to serve for setting the bleaching liquor and for storing the bleaching solution For 100 pounds of wool and 100 gallons of bleaching liquor, 27 pounds of sulfuric acid and 20 pounds of sodium peroxide [or 2½ gallons of hydrogen peroxide (30 volume)] are used

The bleaching liquor is then pumped from the storage into the bleaching tank in such a manner that it is first forced upwards through the wool from below, after which the pump is reversed While the bleaching liquor is being circulated it is gradually heated to 115 degrees and kept at this temperature for three to six hours, according to the degree of bleach desired When the bleaching is finished the liquor is pumped back into the storage tank, the wool lifted and thoroughly rinsed in clean water, first warm then cold, slightly soured with sulfuric acid, and again rinsed The pumps should not make more than 500 or 600 revolutions per minute

For piece goods it is customary to use large earthenware tanks fitted with a winch The goods are run in string form in the bleach bath from four to six hours, at a temperature of 125° F The bleach bath is prepared as follows 250 gallons of water are heated to 125 degrees F and the necessary chemicals are added.

20 quarts hydrogen peroxide (100 volume)
2 quarts ammonia (free of iron), or
2½ quarts silicate of soda (28° Bé)

To prevent too rapid liberation of the oxygen, a so-called "buffer" may be added, which acts as a stabilizer—for example, 4 pounds of pyrophosphate

To determine the exact strength of the bleach bath, it has to be titrated. In titration the bleach bath given above will show.

3 1 grams of oxygen per liter, or
2 15 volume with a pH of 9 4 and a total alkalinity of 8

This is an ideal bleach bath for piece goods After the desired bleach effect is reached the goods are taken out, brought to a string washing machine, rinsed well with fresh water, and acidified with sulfuric or formic acid In some cases a small amount of dye, either methyl violet or ultramarine blue, is added in rinsing to brighten the white

Hydrosulfite Bleach

A cheaper and less severe bleach can be obtained by the use of stabilized hydrosulfite compounds as marketed by various dye concerns Good results are obtained by combining the hydrosulfite process with the hydrogen peroxide bleach.

Bleaching of Specialty Hair Fibers

Owing to the high price difference between white cashmere and colored cashmere, white alpaca and dark alpaca, white rabbit hair and gray rabbit hair, bleaching of the dark fibers is a more or less common practice The bleaching of this type of dark fibers is very difficult Satisfactory results are obtained on the white but no process has so far been found which does not severely damage the dark fiber and lend to further deterioration during manufacturing, impairing especially the soft handle normally characteristic of the specialty hair and fur fibers.

ALTERING THE AFFINITY OF THE WOOL FIBER FOR DYES

Multicolored woolen and worsted goods as a rule are produced either from dyed stocks, tops, or yarns The manufacturer generally weaves them in hundreds of different designs, which compels him to keep a large proportion of his capital tied up in stocks of yarns for long periods Making pieces from undyed wool and dyeing them into plain shades is cheaper and involves a much lower risk because of certain changes in fashion Nevertheless, plain piece-dyed cloth satisfies the public only to a limited extent in spite of innumerable changes and variations made in the design of the cloth Multicolored effects in piece dyeing might be introduced by the use of colored or white silk, cotton, or rayon fibers that are not dyed by the piece-dyeing colors, but the material is no longer all wool To introduce color and novelty effects in piece-dyed woolens, manufacturers have put in their cloth woolen knops, kemps, natural brown and black wools, fur fibers, goose and ostrich feathers, cellophane, and other substances An excellent and popular method of increasing the variety of woolens is to weave in colored yarns with undyed yarns and then to cross-dye them in the piece. The dyes used for dyeing these colored effects must withstand the cross-dyeing without appreciable bleeding into the other fibers The colored yarns are generally dyed with suitable chrome browns, blues, or blacks To avoid bleeding the dyeing is done below the boiling point and in the presence of organic acids This cross-dyeing is usually limited to pale shades.

Decreasing the Affinity of Wool for Dyes

For many years, wool manufacturers have searched for a process by which the wool fiber could be treated to such an extent that it would resist the absorption of the normal wool dyes as used in piece dyeing. Such a process would make it possible to obtain in a cheap and simple way a large variety of multicolored effects on all woolen cloths Considerable research has been devoted to this problem, but so far no process has been developed that would decrease the affinity of the wool fibers toward dyes to such an extent that the treated wool would stay white when dyed together with normal wool Of the various methods, it is worth while to mention the following

1 *Tannic acid* The oldest process is by boiling the wool for one hour in tannic acid, followed by a steeping in a cold bath of stannic chloride

and tartaric acid. The method is quite simple, but it is not used because of damage and discoloration of the wool An improvement of this process, known as Wool Resist CB, was deve'oped by I G Farben by adding some formaldehyde, pyridine and zinc chloride to the tin crystals A further improvement was the *acetylation* process, which considerably reduces the affinity of wool for acid dyes. The wool or yarn is treated with acetic anhydride, glacial acetic acid, and sulfuric acid at 140 degrees F for forty minutes This process is the best resist process known but necessitates special machinery and is quite expensive.

2 *Sulfonation* Treatment with concentrated sulfuric acid (80%) reduces the combining capacity of wool for acid dyes, but the degree of damage is considerable Overcarbonized wool dyes much lighter than normal wool

3 *Glyoxylation* Speakman and Elliott[6] stated that the use of glyoxal produces a resist that is only slightly inferior to acetylation They gave the following recipe

Treat 1 pound wool for one hour at 185 degrees F. in 6½ ounces glyoxal, 12½ ounces sodium bisulfite, in 4¾ gallons water, with ¼ gallon acetic acid

Various processes have been developed using formaldehyde combined with different salts or synthetic tanning materials made from naphthalene sulfonic acids with formaldehyde Even better results are obtained by the formation of the tanning material in the presence of the wool fiber The best results are produced by the formaldehyde and R sa't process The procedure is as follows

100 pounds wool are boiled for thirty minutes in 100 gallons of water containing 50 to 100 pounds formaldehyde (40%—the larger amount gives a better resist, i e , 43 to 1 compared with 30 to 1), 2 to 3 pounds R salt, and ½ gallon sulfuric acid

The wool is then centrifuged, dried, and baked for 15 minutes at 225 degrees F The effectiveness of the resist is estimated by comparing the depth of shade on the normal wool to that on the resist-treated wool, e g , 3 to 0 1 per cent equals a resist ratio of 30 to 1

The disadvantages of all these processes lay in the fact that the resist is far from perfect and is dependent on careful chemical control Their use is mainly confined to tone-in-tone effects Working with formaldehyde is very unpleasant, even with a special plant, the fumes produce a tear-gas effect The formaldehyde R salt process tenders the wool considerably, because it is actually a double carbonizing process Prolonged

[6] Speakman, J B and Elliott, G H *Resist Processes* J Soc Dyers and Colorists, 59, p 185 (September 1943)

boiling in a Glauber's salt and sulfuric acid bath almost eliminates the resist effect

Increasing the Affinity of Wool for Dyes

1. *Chlorination* Of the various methods in use for increasing the affinity of wool for dyes, *chlorination* is the best and most important Chlorinated wool dyes much faster than normal wool in the same dye bath, and prolonged boiling is necessary before a similar depth of shade can be produced on both wools. Use is made of this fact in producing tone-in-tone effects, as some dyes give a marked contrast between normal and chlorinated wools

Phenol-sulfur condensates Townend[7] has shown that the degree of contrast may be accentuated by the addition to the dye bath of retarding compounds, for example, the complex phenol-sulfur condensates The retarding compound is absorbed by both the normal and chlorinated wools, but it slows down the absorption rate of certain dyes more with normal wool In this manner, material may be piece-dyed, not only into tone-in-tone effects but also into very attractive two-color effects Some dyes tend to produce solid shades, whereas others almost reserve the normal wool The contrast can be varied in degree according to the amount of retarding agent used as well as by the selection of the dyes In the ranges of dyes available to give a good contrast, there are many of the regular acid dyes, metalized dyes, and chrome dyes The metalized dyes give excellent contrasts on chlorinated and normal worsted yarns when dyed in the presence of ammonium sulfate only

Carbonizing severely reduces the degree of contrast, especially in woolen goods, therefore, in order to obtain satisfactory contrasts, carbonizing must be done after piece dyeing

2. *Mordanting* By premordanting the wool fibers with various chrome salts, such as sodium bichromate and chromium fluoride, and then mixing such fibers in yarn forms, tone-in-tone effects can be produced by selecting the proper chrome and acid colors This method is limited by the dyes that can be used The affinity can also be increased by the use of potassium sulfocyanide (mentioned in German Patent 231,885) For completeness, it may be noted that salts such as thiosulfate, sodium sulfite, borax, or caustic soda will lead to increased affinity

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[7] Townend, F *Two-Color Dyeing of All-Wool Materials* J Soc Dyers and Colorists, 61, p 144 (June 1945)

PRINTING WOOL

Wool may be printed either in the form of slubbing or yarn or as piece goods. But in either case printed wool materials comprise a minor portion of the finished wool articles. The process of printing upon warp yarn is done largely on carpets. (See page 894.)

Vigoureux Printing on Slubbing

Vigoureux printing of wool slubbing or top is done only by a few mills. Mixed effects by vigoureux printing are obtained by passing the slubbing through a printing machine. The printing machine is operated on the same principle as that used for printing cotton or rayon, except that instead of using an engraved roller to convey the color paste to the slubbing, a roller with raised bars is employed.

The width of the bars on the roller, the depth of the color, and the frequency of the cross-wise stripes on the slubbing determine the pattern or effect. The color paste is composed of dye, a thickening agent such as British gum, acetic or oxalic acid or both, ammonium sulfocyanide, chlorate of soda, and fluoride or acetate of chrome. After the material is printed, it is steamed to complete the operation and back-washed to remove surplus gum and loose color. It is then put through a combing operation which rearranges the fibers. The dyes used for this purpose include a few direct cotton colors, many of the chrome color group, some acid colors, and various specialty products. The requirements are fastness to light and to mild fulling. The direct cotton colors are those having good wool-dyeing properties. The suitable acid colors are those possessing good affinity for the fiber in weak acetic acid baths and showing good fastness to fulling. The majority of these are in the "milling" color group. The chrome colors comprise those that form the chrome lake readily when steamed.

Direct Printing of Piece Goods

To increase the natural affinity of the wool fiber for the printing colors the pieces are normally pretreated with chlorine or, in some cases, with tin salt. In chlorinating, the pieces are passed through a solution containing chlorine, acidified with hydrochloric acid followed by a treatment with bisulfite of soda to remove the chlorine, which is followed by a thorough washing and drying.

Acid and direct colors are recommended for wool printing. Here again fastness to washing and light are the major considerations.

MOTHPROOFING WOOL

In recent years mothproofing of woolen and worsted goods has become more widespread because of the development of more effective chemical compounds and simplified methods of application That there is a definite need for a satisfactory method of mothproofing all woolen goods that are stored during certain periods of the year such as wearing apparel and blankets, as well as upholstery, carpeting, and other bulky products can be seen from the fact that the annual damage attributed to moths and carpet beetles in the United States alone has been estimated at over 100 million dollars

Innumerable substances have been suggested from time to time for preventing damage to wool by moth larvae However, since most of these are of only temporary effectiveness, if not totally ineffective, very few have found use in industry The ideal mothproofing agent should provide permanent protection, that is, its effectiveness should not be altered by frequent washings or dry cleanings, nor should it deteriorate with time or exposure to light or varying climatic conditions

Mothproofing agents may be applied to wool in three general ways

1 By adding substances to the wool which (a) makes it unpalatable to the larvae, or (b) are poisonous to the larvae

2 By storing the wool in a closed container with a volatile substance whose vapor makes the atmosphere inimical to moth life

3 By spraying the wool and its storage place periodically with a liquid insecticide

The latter two methods, although useful in many cases, must be regarded as temporary measures The first method provides either temporary or permanent protection for the useful life of the article, depending upon the substance which is added to the wool

For permanent mothproofing, the substances available to the textile industry at the present time are the various Eulans and Mitin FF. Both Mitin FF and the Eulan brands are effective mothproofing agents because they render the wool useless as nourishment to the larvae and are at the same time nontoxic to human beings Among the various Eulans there are Eulan N, CN, NK, W Extra, BL, and Eulan New With the exceptions of Eulans BL and NK, all are fast to washing and dry cleaning and can be applied during the dyeing process Eulan BL, being soluble in organic solvents, is applied after dry cleaning. Eulan NK is water soluble but is fast to dry cleaning The newly developed Eulan New has even better fastness to washing than the others

Eulans The use of Eulans can be demonstrated in the following ex-

ample using Eulan CN The Eulan CN (pentachloro-dihydroxy-triphenyl methane sulfonic acid) is dissolved in boiling water in the proportion of 1¼ ounces to 1 gallon of water The clear, hot solution is added to the dye bath when the latter has reached a temperature of 120 to 130 degrees F For satisfactory results, the amount of Eulan CN added to the dye bath should be equal to 1½ to 2 per cent of the weight of the wool The addition of 3 per cent affords protection against Attagenus and Anthrenus beetles in addition to moths It is interesting to note that Eulan CN goes onto the fiber quantitatively from an acid bath and is not impaired by the subsequent finishing operations

Mitin FF Mitin FF is a colorless organic dye a halogen-substituted acylamino sulfonic acid (U S Patent 2,311,062). Its affinity to wool is so high that it is quantitatively exhausted from a neutral bath at 140 degrees F It is fixed by the fiber even faster than the Eulan brands, withstanding not only washing but also the fulling operation It can, therefore, be applied to the wool in stock, top, or yarn form as well as combined with piece dyeing The minimum amount of Mitin FF required for adequate mothproofing is 2 per cent of the weight of the wool

An example of a proved method of application of Mitin FF is as follows Mitin FF is prepared by dissolving the required amount in boiling water in the proportion of 1 to 10 This solution should always be made up fresh It is then added to the dye bath at about 85 degrees F The temperature is gradually increased to 140 degrees F during the next twenty minutes, after which 1 per cent acetic acid is added and the goods run approximately forty-five minutes at 140° F

In addition to the Eulans and Mitin FF, there is a large group of compounds that cannot be classed as permanent mothproofing agents, but which give good protection under limited conditions Among these are

Amūno This compound is an organic fluoride which can be applied to wool piece goods in the following stages of manufacture:

1 Goods that are dyed after carbonizing—in the final rinse after dyeing.

2 Goods that are carbonized after dyeing—in the final twenty minutes of the neutralizing bath.

3 Goods that are bleached—in the final rinse after bleaching

For the proper application of the Amūno, the pieces must be absolutely free of soap stains, oil marks, or any resist stains, and the extractable matter should not exceed 0 6 per cent of the weight of the goods The goods can be treated in a dye kettle, dolly washer, or any machine in which they can be agitated continuously Amūno is added in the pro-

generally used for creating an atmosphere inimical to moth life are para-dichlorobenzene and naphthalene, both of which are solids with appreciable vapor pressure at normal temperatures These substances are effective only when the goods are stored in sealed containers or well packed in stout paper packages. The crystals of para-dichlorobenzene or flakes of napthalene are scattered about the goods It is obvious that such protection is maintained only as long as the vapor concentration itself is maintained

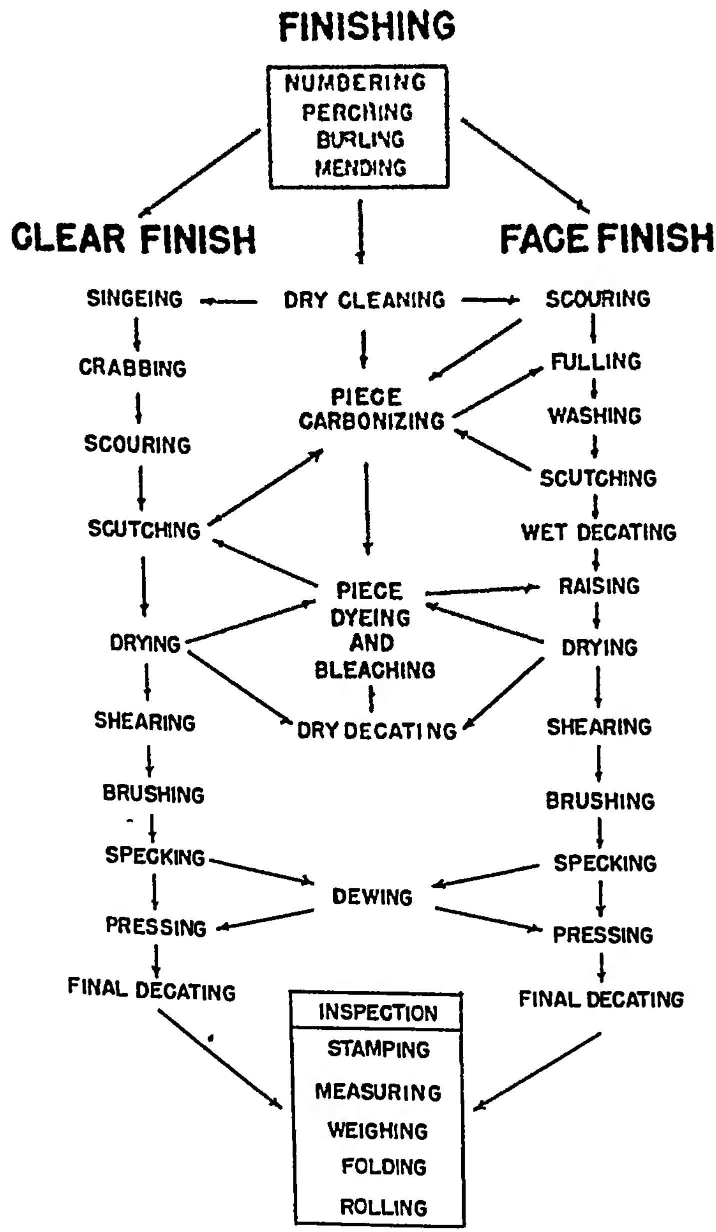
Insecticidal sprays Insecticidal sprays, often described as solvent contact sprays, are used primarily for combating insecticidal infestations in buildings and storage places. These materials consist essentially of powerful insecticides—e g , pyrethrum, dissolved in a volatile solvent, such as "white spirit" They will destroy moths or grubs with which they come into contact Their insecticidal action is only temporary, and if by use of these sprays goods are to be kept mothproof it is necessary that the sprays be applied at frequent intervals A further limitation of their use is the difficulty of ensuring penetration into a mass of material

DDT The use of DDT as a mothproofing agent was developed during World War II, and it was found that 0 1 per cent applied to wool gives adequate protection DDT can be applied as a solution in oil at certain stages in processing, or as a solution in solvent It may be useful to apply it in oil to protect tops, rovings, yarns, or pieces while they are stored, however, the protection would be lost on wet processing

Of far more importance seems to be the development of the use of DDT in the form of a fog for the control of clothes moths in wool-storage houses as well as in the storage rooms of woolen and worsted mills In this method, known as Thermal Aerosol Fog, a 5 per cent solution of DDT and oil is atomized by compressed air into a fine mist by means of a fog generator. It appears that the Thermal Aerosol Fog containing DDT may provide a much more economical pest control procedure for use in woolen and worsted mills than any other older method of warehouse pest controls

The National Institute of Cleaning and Dyeing reported recently the successful application of Erustomoth, a mixture of DDT and an absorbant powder for the mothproofing of wool garments The treatment of the garments is combined with the extracting process after dry cleaning

Gammexane More recently benzene hexachloride (Gammexane), "an insecticide with outstanding properties," has been stated to be highly toxic to clothes-moth grubs



Flow chart of finishing and dyeing

Chapter 19

WET FINISHING OPERATIONS

FINISHING relates to all those processes to which woolen and worsted goods are subjected after they leave the loom and before they are presented for sale. The primary object of finishing is to enhance the quality of the cloth, imparting to the woven fabric a specific appearance and handle in order to render it attractive to the purchaser.

Four Factors to be Considered

Finishing processes are extremely varied The number of operations and the degree of treatment depend on the following factors

1 The type and quality of the raw wool used to make the fabric
2 The type of yarns used in the fabric
3 The design or structure of the fabric
4. The specified surface character and handle to which the finished fabric must adhere

1 Type and quality of the raw wool The type and quality of the raw wool influences the felting and shrinking properties of the fabric during the finishing operations

The ability to felt is peculiar to wool and related animal fibers The degree, however, to which animal fibers will felt depends on their nature, quality, and physical and chemical structure The felting properties are more pronounced in the fine merino wools than in the crossbred or in the coarse, long wools The fibers of the goat and the camel families, such as mohair and camel's hair, have a low felting ability due to their much smoother scale structure

Cotton, rayon staple fibers, protein fibers, and synthetic fibers are nonfelting in character Therefore, when a cloth is a mixture or combination of wool and nonfelting fibers, such as staple rayon, the finishing treatments have to be of such a nature that the natural properties of each are preserved and exploited to the best advantage Not only does each fiber type and subtype differ in its felting and its shrinking abilities but also in its behavior toward the numerous chemicals employed in the wet-finishing and dyeing processes These facts impose upon the wool and worsted finisher, if the best results are to be obtained, the necessity of considering the character of each material with which he is dealing

2 *Yarn type* Wool is spun into woolen and worsted yarns which are dissimilar in formation The handle and appearance they produce in the finished cloth are markedly different. A woolen fabric will felt more readily and to a greater degree than a similar worsted fabric, as the fibers of the woolen yarns, due to their crosswise relationship, tend easily to become further entangled with each other In a worsted-yarn fabric the fibers lie almost parallel to one another throughout the whole length of the yarn and, therefore, have not the opportunity to felt so readily.

The amount and the direction of twist present in a yarn also have a definite influence on the felting property, as well as on the surface character and the handle of the finished cloth. The fibers of a soft twisted yarn react in an entirely different way from the fibers of a hard-twisted yarn Consequently the appearance imparted by finishing to fabrics such as crepes, which are made from hard-twisted yarns, is different from that of flannel, composed of soft, twisted yarns of the same material In twills the direction of the twist has a definite bearing on the clearness of the twill line in the finished state.

There is quite a difference in the felting properties of yarns in the natural or undyed and the dyed condition even when spun from identical material The yarn composed of dyed fibers has already been subjected to some fiber shrinkage while being dyed in the stock, top, or yarn state, thus it is necessary, when making a piece-dyed cloth that is to be equal to a mixture, or one composed of solid colored yarns, to make suitable allowances.

3 *Fabric structure* The design or structure of the cloth controls, to a large extent, the influence of the finishing processes The structure varies according to the weave, the yarn count of the warp and the filling, and the number of ends and picks per inch These factors greatly influence the varying widths and lengths of fabrics as they pass from loom to finished cloth There is great diversity in the contracting and shrinking properties of weaves

E Midgley[1] reported a variation of contraction from reed to gray cloth width of from 4 to 12 per cent for nine different weaves, using the same warp and filling yarns The additional width shrinkage from the gray to the scoured cloth varied from 3 to 10 per cent Similar contractions and shrinkages are caused by using the same weave but changing the yarn count of the filling and the number of picks per inch

4. *Character and handle* In general, all classes of woven fabrics change in character, handle, weight, thickness, strength, and elasticity

[1] Finishing of woven fabrics (1929) Longmans

Chapter 19

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during the finishing processes The wool fabrics as they come from the loom in the raw or gray condition have a dull, lifeless appearance and a loose thready structure which may be easily unraveled When a woolen fabric is subjected to the fulling and raising operation, the thready appearance totally disappears, being altered to resemble a felt with a nap of fibers drawn from the body of the cloth Consequently, finished kerseys, doeskins, and fleece fabrics have very little resemblance to the respective fabrics as they left the looms

The finishing of worsted fabrics generally does not result in the distinctive change produced by finishing most woolen fabrics, for the character of the worsted weave or effect is not only maintained but further enhanced, in serges and gabardines, for example Fancy-colored worsted suitings in their finished state and in the gray are very similar but it is not difficult to distinguish the unfinished from the finished fabric The latter has a very slick, soft handle and a smart appearance which is brought about by careful scouring and pressing and removal of the fiber fuzz from the surface by singeing and shearing.

Types of Finishes

The types of finishes applied to woolen and worsted fabrics are almost innumerable For general classification the various types of finishes may be subdivided into three mains groups (1) clear finish, (2) face finish, and (3) modifications of the clear or the face finish

1 *Clear finish* The main characteristic of a clear-finished fabric is its clear, even, and threadbare surface The weave and the colors are prominently developed and distinct The clear-finished goods receive either no fulling at all or only sufficient to produce the necessary firmness and handle Most worsted fabrics fall into this class.

2. *Face finish* The main characteristic of the face-finished fabric is that it has a nap or pile of fibers on the surface The weave does not show at all or is indistinct, and the colors are subdued and softened These effects are brought about by fulling and raising In some instances, for example, velours, the pile stands erect from the fabric, whereas in others, broadcloths and kerseys, the fibers are laid flat in one direction and treated to give a lustrous appearance When full shades are employed, the character of the cloth is very rich The face finish is generally applied to woolen fabrics

3 *Modifications of the clear or the face finish* The finisher can produce a great variety of finishes in between the two main types, by

simple modifications of them Among the worsted fabrics, for example, there is the popular unfinished worsted The weave and the color designs are more or less subdued because the face of the fabric is not shorn clear, it still carries a surface fuzz of loose and straggling fibers The handle is soft and flannel-like The melton and the covert-type finish of woolen fabrics is produced through heavy fulling, ending with steaming, brushing, and pressing. The surface shows a fibrous appearance with the weave not visible, similar to a felt.

Fabrics may even carry both types of finishes an example was the 22-ounce serge, which was made especially for U S Army uniforms worn in Alaska during World War II The face of the cloth was clear, whereas the back was finished with a velourlike nap

Numbering, Perching, Picking, Burling, Mending

Prior to the finishing and the dyeing processes, woven fabrics are subjected to numbering, perching, picking, burling, and mending All cloths as they leave the loom contain imperfections to some degree The defects generally found in wool cloths may be classified into three groups:

1 Those due to impurities such as burrs, straws, skin pieces, pitch stains, and kemps in the raw materials

2 Those incurred in the spinning processes that show up in the woven fabrics as knots, slubs, and thick and thin yarn

3 Weaving defects such as missing warp and filling threads, "ends out," "picks out," or mispicks, holes, harness skips, and wrong draws, and also oil and graphite stains

To establish and to correct their imperfections, woven fabrics after leaving the loom are subjected to the following processes

Numbering In order to identify and to establish a record of each piece, it is necessary to stitch or mark it with reference numbers The numbers generally indicate (1) the number of the "cut," and (2) the number of the style The numbers are usually sewn with cotton thread on the face of the front end of each piece For each sample piece of a new style, a numbered record is kept referring to the particular finishing processes and degree of treatment to which each sample has been subjected By using this record as a reference, the finisher is able to subject the regular pieces to the same processes and degree of treatment undergone by the sample piece, in this way obtaining identical results

Perching. Perching consists of examining the cloth and mark-

ing with colored chalk all imperfections which should be eliminated in the subsequent processes The machine used for inspection is known as a perch The modern perch is designed so that the operator may give the cloth careful and thorough inspection with a minimum of effort The machine, which is power driven, has a forward, a reverse, and a variable-speed drive The machine is controlled either by a small switch that the operator holds in his hand, or by a foot switch, either of which can start or stop the cloth instantly The cloth passes before the operator at full width and free of wrinkles Inspection is made in two ways: (1) the goods between the light and the inspector examining against the light, (2) inspecting the surface of the goods only, with the light on the goods

The measuring and the weighing of the cloth may be combined with perching In such cases the perch is fitted with a yardage counter and the delivery of the cloth is so arranged that it drops from the folder onto the platform of a Toledo scale, the beam of which hangs between the frame of the perch (Fig 1)

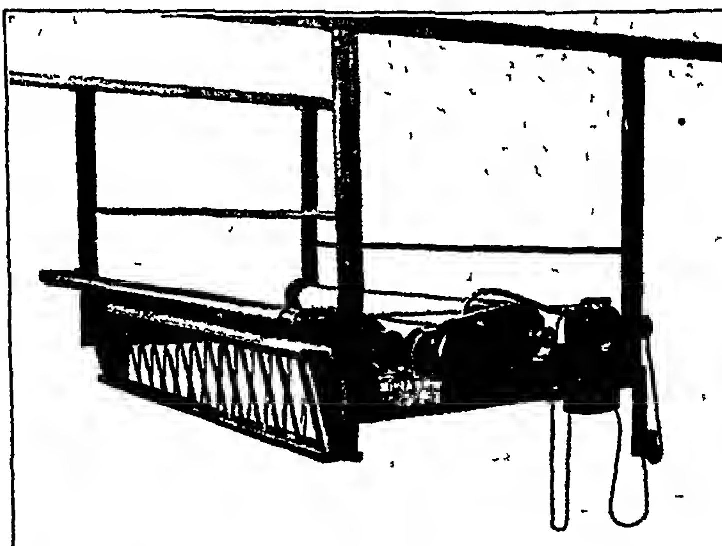
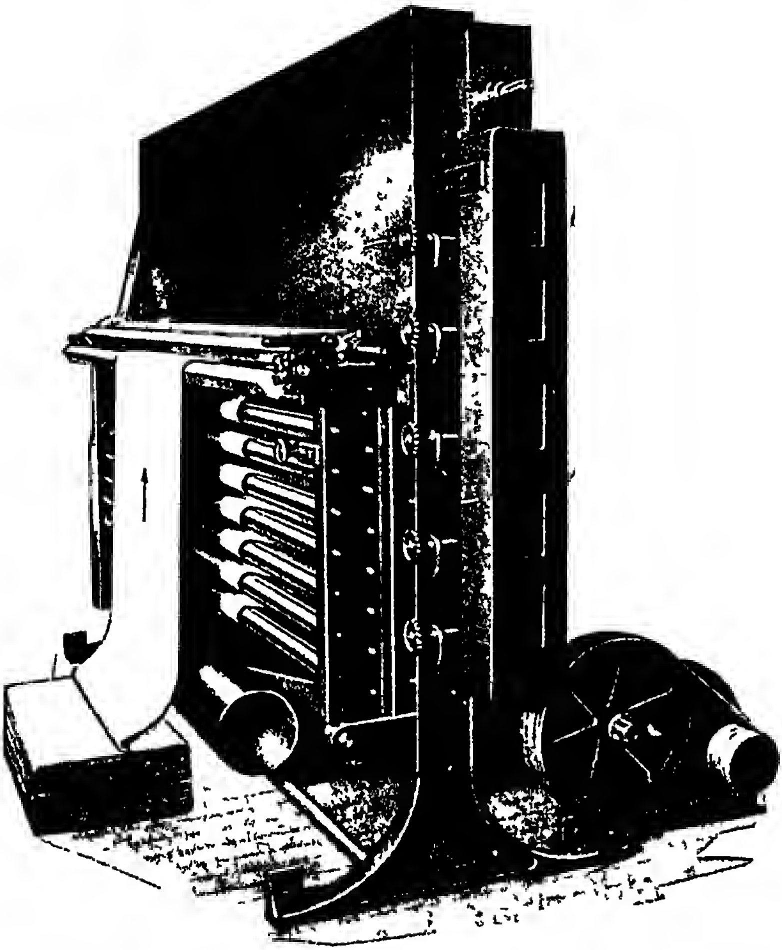


Fig 1 Power weave room perch (*Courtesy Birch Brothers, Inc*)

Picking This process consists of extracting from the face of the cloth all extraneous matter such as neps, slubs, burrs, hairs, and straws In some mills this process is referred to as *specking* (Fig 2) The removal of these substances is generally done by hand, but in



(Fig 2 Worsted and woolen despecker—twelve contacts
(*Courtesy Parks & Woolson Machine Co*)

fabrics having a high nep count, it is economical to run the cloth through a sanding or a despecking machine first

Burling In this process the back of the cloth is first examined by the burler and all snarls, slubs, straws, etc, are removed The thick warp threads and the filling threads are drawn out and replaced, and the knots opened Afterwards, the burler examines the face of the cloth, pushing such irregularities as remain (loose ends and curls) to the back, in order that the face of the cloth may be as free as possible of irregularities and imperfections

Usually burling is carried out on a table with a sloping top and a smooth surface which allows any thick places or knots to be easily detected when the hands are passed over the cloth Warp threads must not be cut below the knot The knot should be opened to allow the two ends of yarn to hang together, thus avoiding a small hole which would be created if the two ends of yarn were apart This work is done with the aid of burling irons and scissors

Mending This word is used to describe the insertion of yarn in the woven fabric where any warp or filling threads are missing Every missing thread must be carefully hand woven into the piece in exactly the same manner as if it had been machine woven Knowledge of weave construction, therefore, is very important The faulty places are repaired by sewing in new lengths of yarn with a needle, beginning and finishing at the back of the cloth so that the loose ends of the thread can be cut off. This corrective work is absolutely necessary on clear finished fabrics However, on heavy fabrics and on fabrics to be fulled, smaller imperfections may be left in and they will be invisible in the finished cloth. This work is very delicate and time-consuming, which makes it expensive It is performed entirely by women In some cases it becomes necessary to return the goods after scouring for additional mending of places that escaped inspection in the gray. Missing threads are always mended in high-priced, quality goods.

WET-FINISHING OPERATIONS

The goods are now ready for the finishing processes and are subjected to a definite routine of operations selected to produce the desired finish or character of the goods The following procedures for finishing woolen and worsted goods are given in the general order in which they occur but not necessarily in the definite sequence, since the procedure varies according to the desired result

The operations in wet finishing are dry cleaning, singeing, crabbing, piece scouring, fulling, carbonizing, scutching, beaming, wet decating, blowing and raising

Dry Cleaning

The successful application of dry cleaning to woolen and worsted fabrics is a recent development The process, also known as the Derby process, was introduced in 1939. Because installation is quite expensive, however, only a few mills have made it. The diagram (Fig 3)

illustrates the method used The cloth enters the totally enclosed machine through a seal into a soaking compartment containing about 100 gallons of trichlorethylene solvent The cloth travels in its full width over and under rollers, with the lower roller immersed in the trichlorethylene The cloth then passes between a pair of draw rollers, that keep it under tension as it is drawn over a vacuum slot and passed through a second pair of draw rollers, which are synchronized with the first Through a seal it then enters a drying compartment and runs over five dry cans The clean, solvent-free cloth leaves the drying section through a seal and between a pair of draw rollers at the top

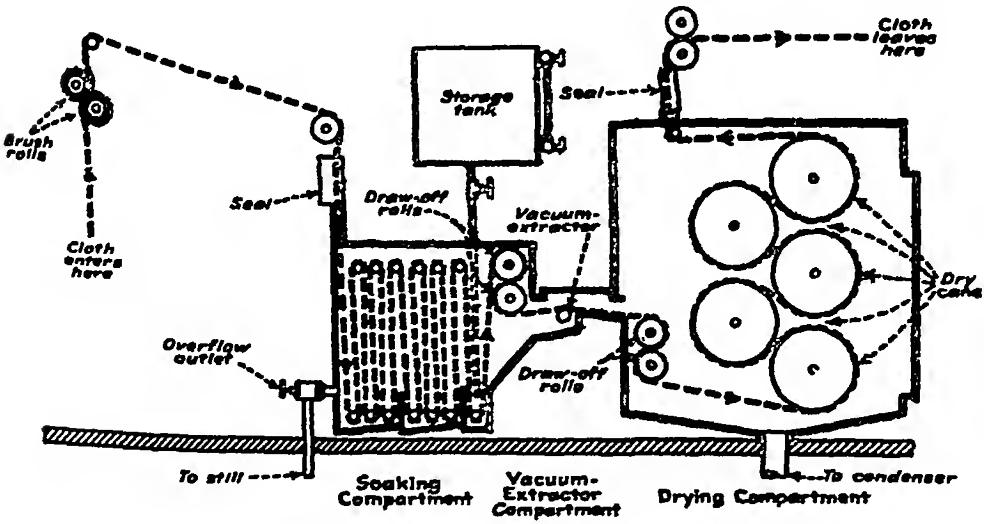


Fig 3 Continuous dry cleaner (*Courtesy The Derby Co*)

From a storage tank above the machine, clean solvent is fed automatically into the last section of the soaking compartment The solvent then flows counter-current to the direction of the cloth until it reaches the first section of the compartment The solvent, now saturated with spinning oils and other impurities from the cloth, overflows into a still where it is recovered continuously by ordinary steam distillation The solvent vapors, mainly from the drying compartment, pass into a condenser and then through a separating chamber for removal of any water that may have been collected The solvents from the still pass from the condenser and are collected in a sump tank from which they are pumped back into the storage tank at the top of the machine, where they are ready for reuse

Singeing

Singeing consists of burning off the free, projecting fibers from the surface of the cloth, leaving it perfectly smooth and bare It is applied only to fabrics to be clear finished There are two methods for removing this fuzz from fabrics, gas-flame singeing and plate singeing.

Gas-flame singeing (Fig 4) is the most common method used in the United States It is performed by passing the cloth in full width at a rapid speed over open gas flames The machines are built to provide singeing on one or both sides of the cloth in one run

Plate singeing is done by passing the flat goods over gas—or oil-heated oval plates and is usually used on face-finished goods It produces a clear and highly lustrous surface on all kinds of linings, particularly those of mohair, or mohair and cotton used in men's and ladies' suitings, as well as men's coatings

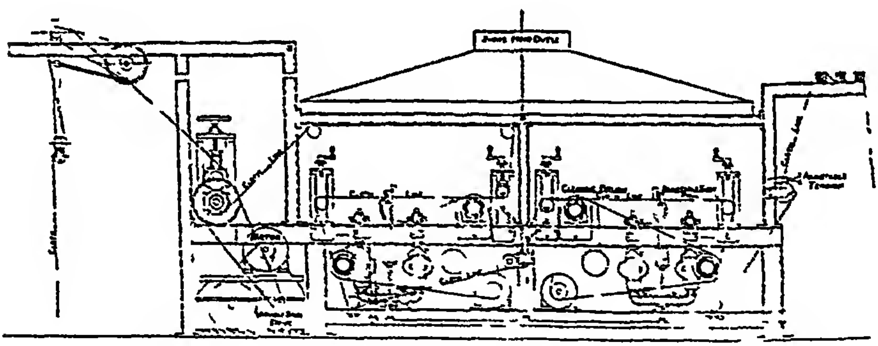


Fig 4 Four-burner horizontal gas-flame singeing machine. (*Courtesy Birch Brothers, Inc*)

Crabbing

The object of crabbing or setting is to fix permanently the warp and the filling threads in a regular manner by the removal of the irregular hidden strains, thus preventing the formation of cockles, crimps, creases or other forms of uneven shrinkage in later stages of finishing.

The method of crabbing and the degree of treatment to which the worsted fabric is subjected, depend on the quality of the fibers, the twist of the yarns, and the cloth construction. Special precautions have to be taken with fancy-colored worsteds, because of the risk of bleeding of the colors English crabbing and continuous crabbing are the two methods used

English crabbing The goods are passed in full width through boiling water onto a roller with or without top-roller pressure The machine may be used in one unit or in series of three or four units Working in series has the advantage that both ends of the pieces receive equal treatment Through the transferring of the piece from one machine to the next, the top end of the first machine will be the bottom end of the second machine, thereby preventing shadiness (end to end) in the succeeding dyeing process In a three-series crab, the first two units operate with boiling water for five to ten minutes, the last unit employs cold water to complete the setting of the fabric, with

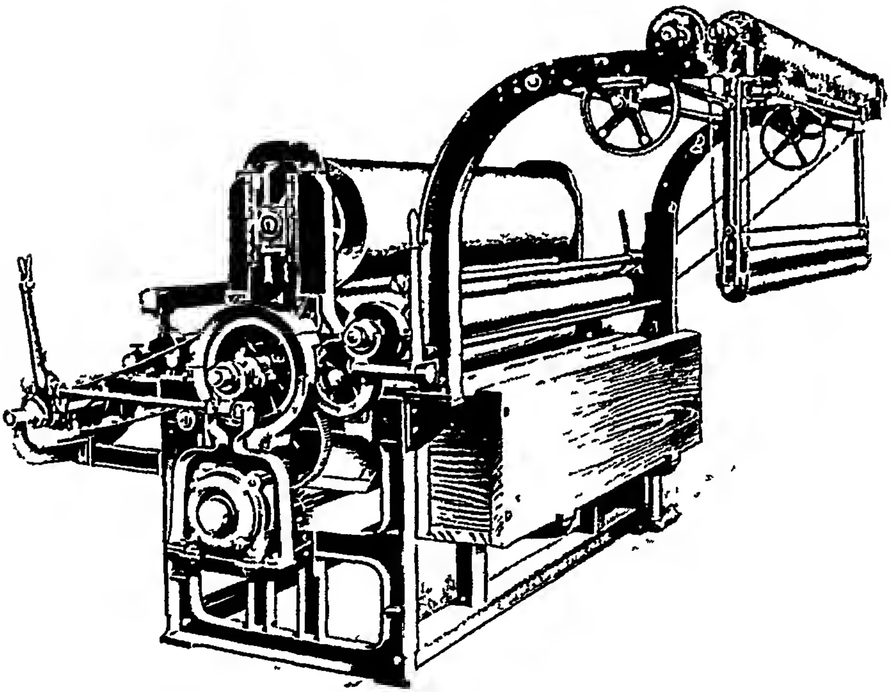


Fig 5 English crabbing machine with folder arms and rear water tank (*Courtesy David Gessner Co*)

either slow or rapid cooling as desired A unit of an English crabbing machine is shown in Fig 5

Continuous crabbing In this method the cloth passes in full width through a series of tanks, as shown in Fig 6, for instance Each tank is equipped with immersion rolls, steam piping, cross spraying, and overflow and at the end is a pair of squeeze rollers The pressure is applied by means of air cylinders Before each nip there is a pair of spirally fluted, opening rollers for the removal of wrinkles and double selvages A spray pipe for rinsing is also set ahead of each nip This type of machine is used not only for the crabbing of worsteds but it also has been found suitable for wool-rayon blends, where the goods are to be set, scoured, and rinsed in preparation for dyeing

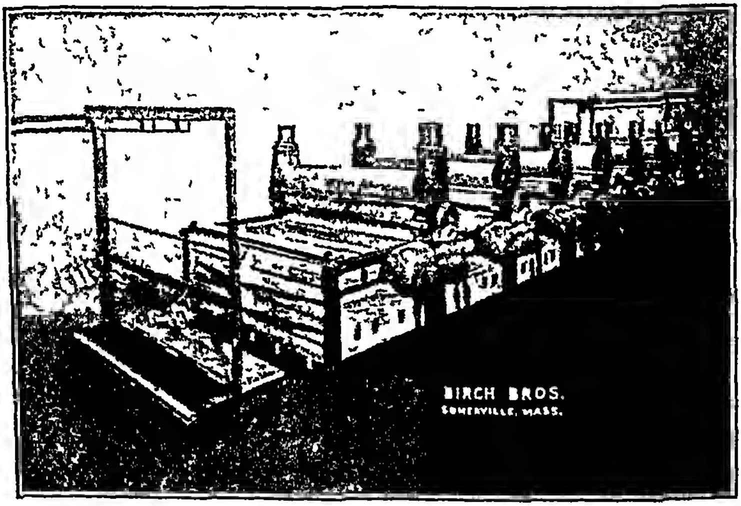


Fig 6 Seven-tank continuous crabbing machine
(*Courtesy Birch Brothers, Inc*)

Piece Scouring

Piece scouring is necessary to remove the oil or emulsion with which the wool was treated in spinning, the sizing applied to the warp before weaving, and any other foreign matter, such as oil spots and dirt, which the yarns and fabrics have acquired during manufacturing operations

In woolen goods these impurities may be from 15 to 20 per cent of the raw weight of the cloth In qualities containing much reworked

wool, the loss, due largely to the grade and the amount of oil applied, may amount to as much as 30 per cent In worsted fabrics, where less spinning oil is used than on woolens, the loss of weight is between 5 and 10 per cent Occasionally, before scouring goods containing pitch or tar stains, it is necessary to run the goods through a depitching solution to loosen up the stains

Water for scouring The type of water used in scouring piece goods is just as important as in wool scouring A soft water, with hardness of less than 5 grains per gallon, should be available to avoid the formation of insoluble calcium and magnesium soaps on the surface of the goods, which would cause serious trouble in piece dyeing Even with such soft water, the use of products such as sodium hexametaphosphate and sodium tetrametaphosphate has been found advantageous, especially in the high-speed washers These water softeners are generally used in the final rinse to remove the last traces of soap

Scouring agents The scouring agents used are the same as for scouring loose wool, namely, soap and weak alkalies such as soda and ammonia It is an emulsification and saponification process combined with mechanical action The amounts of chemicals are adjusted in accordance with the impurities present and are generally used in dilute solution For fine worsteds 2 to 4 gallons of a 5 per cent soap solution per piece will be sufficient, whereas for heavy woolen coatings 5 to 9 gallons of soap per piece and a soda solution 1½ to 3 degrees Bé are required

In addition, many synthetic detergents such as sodium alkylaryl sulfonate, lauryl sulfate, sodium oleyl sulfate, polyether alcohol condensates, and sulfonated fatty acid amide derivatives, whose actions are unaffected by hard water, are of special value in scouring goods when felting is to be avoided and also in scouring yarn-dyed goods of delicate shades A further advantage of synthetic detergents for scouring is that, because of their nonalkalinity, the harmful effects of alkali on both fibers and certain dyes can be avoided These products have good cleansing action in a neutral or even acid bath Furthermore, they can be rinsed more quickly and easily than any common soap If desired, the detergent action of these compounds can be improved still further by the addition of sodium tripolyphosphate, tetra-sodium pyrophosphate, or tri-sodium phosphate

Scouring is done in three different types of machines, the string washer, the broad washer and the cylinder washer.

String washer The most common is the string washer, also known as the rope or the dolly washer, in which the cloth is sewed into an

endless string or rope which passes between two rollers (wood, rubber, or Monel metal or similar alloy) as illustrated in Fig 7 Eight to ten pieces can be handled side by side in one machine According to the weight and structure of the cloth (heavy, medium, or light), top rollers are used respectively Each string is kept in its position by guide rings or sticks to avoid entanglement with adjacent pieces The top roller serves as a squeeze roller and the bottom roller is positively driven The strings are then allowed to float in the scouring liquor through the bottom of the washer, till they are returned to the rollers in their continuous passage

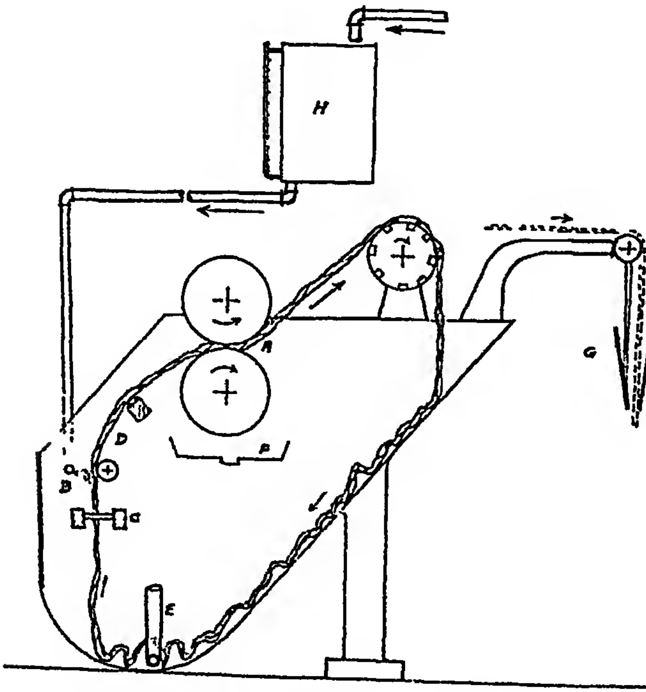


Fig 7 Diagram of a string washer

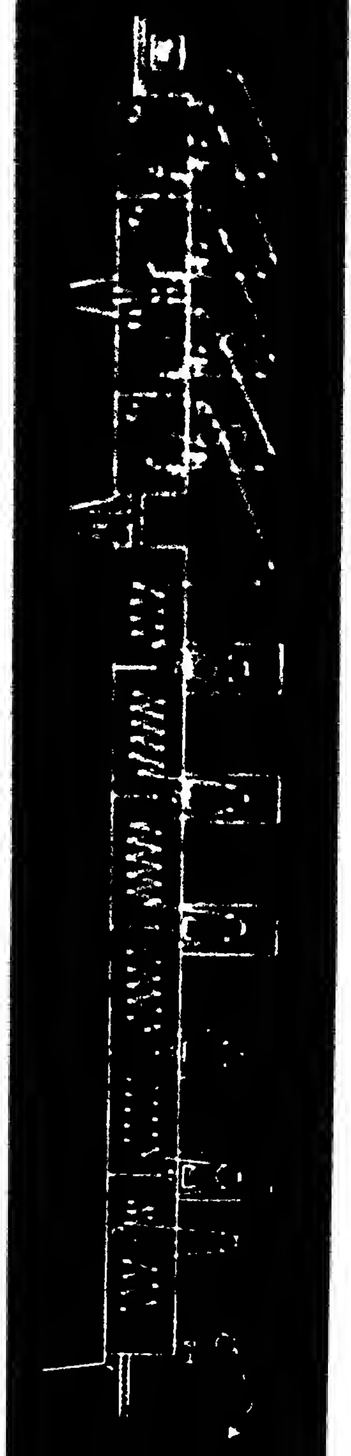
A—Squeeze rolls
B—Soda and water inlet
C—Wooden guides
D—Guide bar
E—Overflow pipe
F—Suds box
G—Folder
H—Soda supply tank

The running time for different goods varies according to the weight from one to four hours The temperature of the scour-bath is kept at about 100 degrees F (blood temperature) during this first phase of scouring to speed emulsification and saponification of the oils, which take from ten minutes to one hour and are characterized by the formation of lofty soap suds

In order to remove the emulsified oil, rinsing is necessary This is done by dropping the scouring liquor and opening the warm water valves slowly until the greater part of the soap is flushed away Rinsing may require one-half to two hours according to the weight of the goods The last traces of soap and alkali are then rinsed away with large amounts of cold water

composed of six interconnected bowls, using the counter-current principle The back and forward movement of the cloth, which effects the best rinsing with the greatest economy in the use of hot water, is the feature of this section In the final section, the cloth receives a cold-water rinse.

The machine is approximately 110 feet long, including a soaper For a full load, 600 yards of cloth are needed The manufacturer claims that 30 to 35 yards can be put through per minute but actually most of the worsted mills run from 45 to 55 yards per minute The machine is so designed with automatic controls and stops that it can easily be run by three men one on the



(Courtesy Riggs & Lombard)

feeding line, one on the delivery end and one man for supervision

At a speed of 40 yards, the total scouring time for a 60-yard cut is approximately twenty minutes Because of this short washing period, the soap used must be readily soluble and easily rinsed Low-titer soaps are of special merit for this purpose The concentration of the soap solution used in the soaper for the average run of woolen and worsted goods, 8 to 16 ounces per linear yard, is about 3 per cent soap (dry basis) fortified with 2 per cent soda ash

A similar machine built by another manufacturer consists of six to nine dolly washers arranged in a train as in the continuous cloth washer just described with the exception that the individual bowls are interconnected by a pipe rather than joined together One mill using such a machine reported that it handled 450 pieces per day in two shifts using only four men per shift one for the sewing, two on the washer, and one on the scutcher Compared with the older dolly washer, the machine showed a labor saving of 50 per cent and considerable savings in water, steam power and chemicals

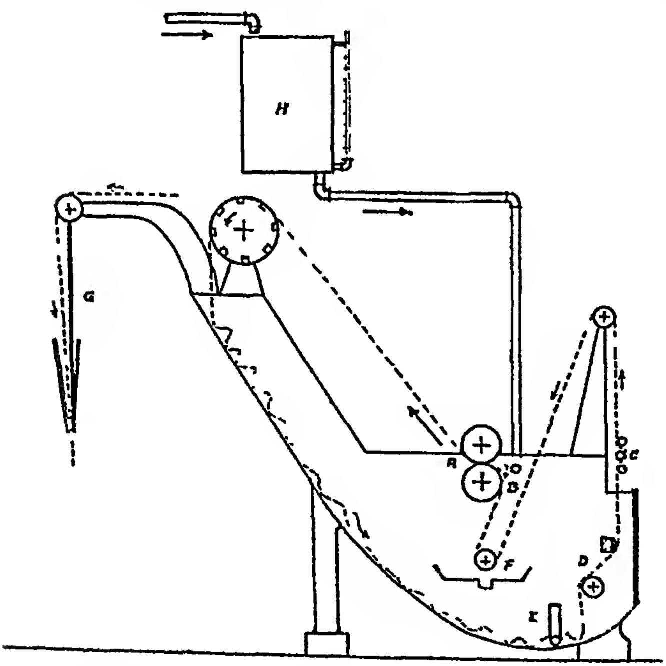


Fig 9 Diagram of a broad washer.

A—Squeeze rolls
B—Soda and water inlet
C—Centering rolls
D—Guide bar
E—Overflow pipe
F—Suds box
G—Folder
H—Soda measuring tank

As in raw wool scouring, each bowl of the wash section must be charged with sufficient scouring agent at the start to attain a clean piece of cloth right from the beginning.

Broad washer Certain fabrics that are liable to crease in the dolly washer must be washed in the full width in a broad washer (Fig 9)

This applies especially to light dress fabrics and clear-finished worsteds. The cloth is run in full width over a series of guide rollers and between a pair of small, hard rubber squeeze rolls, which can be adjusted for various pressures In such machines six to eight pieces are sewed together into an endless band and run from one to four hours, following the same procedure as in the dolly washer.

Cylinder washer Very fine crepes and lightweight dress fabrics have been scoured to good advantage in laundry wheels The individual pieces are put in bulk into each compartment, of which there are three to a machine The perforated cylinder, enclosed in a hood, tumbles the pieces as it oscillates back and forth, performing the necessary mechanical action Total scouring time is from one to two hours This type of scouring produces a much better crepe than is possible in a string or a broad washer

Fulling or Milling

The process of fulling or milling is peculiar to the woolen industry because of the characteristic felting quality of wool and certain hair fibers The theoretical background of fulling was discussed in the chapter on the physical properties of wool Three factors are involved in fulling moisture, friction, and heat. Moisture, the most important factor, causes the wool fiber to increase in elasticity and capacity for elongation Under the influence of friction or pressure the wool fiber is forced to travel in the direction of its root (on account of scale formation) until it strikes against adjacent fibers and becomes entangled with them, resulting in a compact matting or felting. The heat produced by the constant friction of the pressure rollers and the trap assists greatly in the movement of fibers among themselves and increases their plasticity, which speed up the process The best fulling temperature is between 90 and 100 degrees F.

Moisture is provided in the form of a soap or acid solution When soap is used, the pieces are soaped in preparation for fulling by running them through a machine designed for this purpose It consists of a soap box with a rubber roller wringer that distributes the soap and removes any excess The concentration of the soap solution, i e ,

the amount of soap used, depends upon the felting quality of the wool and the shrinkage desired. For slight felting a 5 per cent soap solution (70 per cent strength) is sufficient, whereas for heavy uniform goods a 10 per cent soap solution (70 per cent) is required. The alkalinity of the soap depends upon whether the cloth is scoured or unscoured When in a scoured condition a neutral soap is used. For gray goods, an alkaline soap containing approximately ½ to 1 per cent of soda, which will aid the saponification of the oil, is preferred

The main purpose of the soap is to reduce the friction of the piece in the mill and to prevent the formation of flocks and of fulling streaks or uneven places Care must be taken that no excess of soap is present because of the possibility of the goods slipping, which would reduce the fiber movement

To prevent bleeding of colors, weak acid solutions are preferred as milling agents for fabrics such as felts and white woolen blankets with colored borders The quantity of acid used varies from 2 to 4 per cent, depending upon the weight of goods to be fulled The fulling time may vary from five minutes to six hours, depending upon the amount of felting which is desired.

There are two kinds of fulling machines or mills the stock or hammer fulling mill and rotary fulling mill

Stock or hammer fulling mill Into this machine (Fig 10) the piece is put in bulk and two stocks or hammers work on or pound the cloth Through this action the threads of the cloth are moved about and the fibers begin to felt The amount of shrinkage of the cloth depends upon the time this action is continued The shrinkage or felting takes place in length and width at the same time there are no means

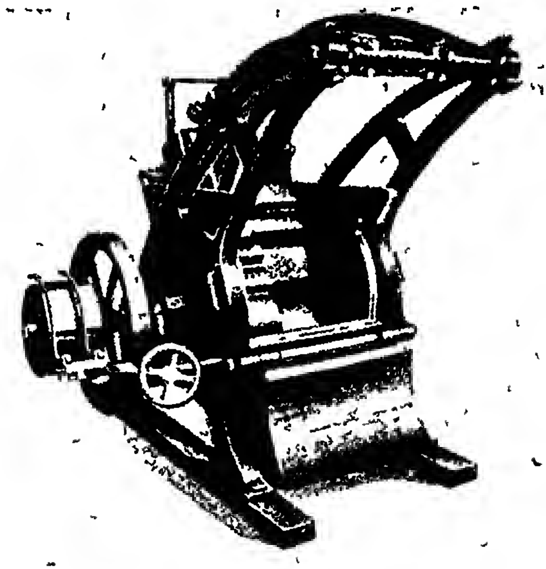
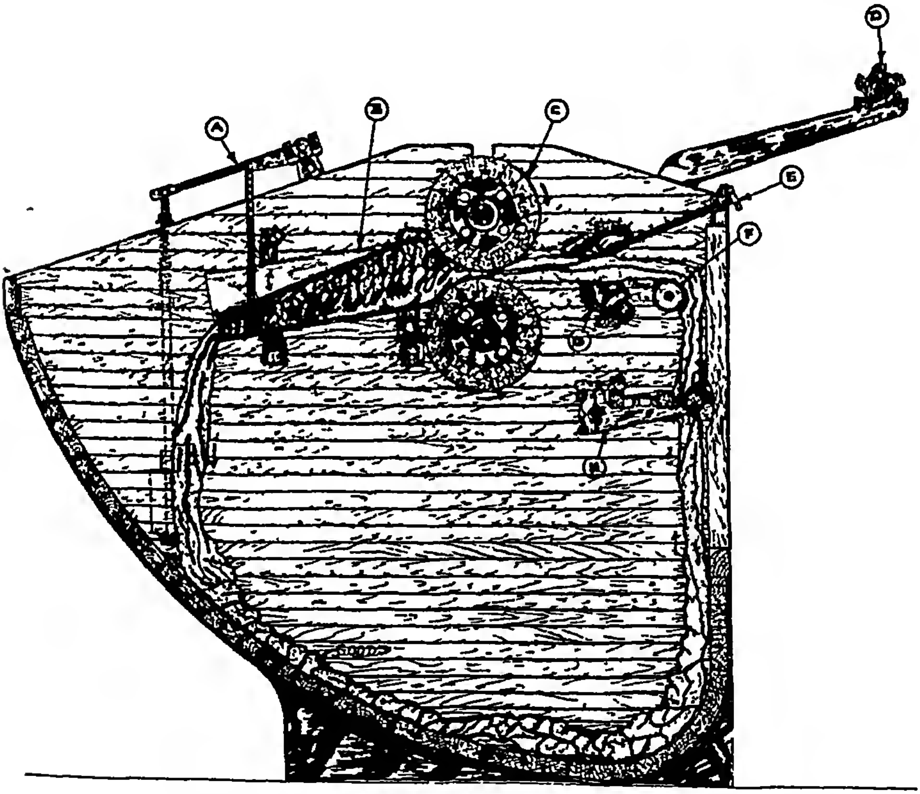


Fig 10 Stock or hammer fulling mill

to control separately the shrinkage in width and length The machines are built in different sizes, and from one to four pieces can be milled at the same time, depending upon the weight of the goods Stock fulling mills are preferred for woolen and worsted fabrics when a certain crepe or sporty effect is to be developed and a small amount of felting is required, and they are used extensively on shoe and heavy felts

Rotary fulling mill In this machine pieces travel in rope form in a manner similar to that found in a string washer Two or more heavy



A—Compound weighting
B—Crimping box or trap
C—Main rolls
D—Outboard delivery roll
E—Adjusting nut for tension
F—Tension whip roll
G—Diamond eye tension
H—Stopmotion

Fig 11 Diagram of a rotary fulling mill
Specially prepared by the James Hunter Machine Co

rollers, with considerable pressure on the top roller, pull the cloth through the machine Until recently these fulling rollers were made of hard wooden blocks on an iron cylinder, but now rubber and fiber composition rollers are used for this purpose The latter have proved very successful because they require less turning down than wooden rollers and last longer From the rollers the goods enter a wooden crimping box (also called a trap), into which they are crammed temporarily by a weighted lid or cover as illustrated in Fig 11 This compression of the goods acts on the warp of the cloth and causes the piece to shrink in length From the crimping box the goods slide down an incline into the bottom of the trough from where it is lifted and passed through a knocking-off device or stop motion The stop motion serves to stop the machine when an entanglement occurs and at the same time aids in keeping the individual strings apart The cloth now passes over a guide roller into throats These throats may consist of two adjustable side rollers or the adjustable diamond eye guide (Fig 12) The diamond eye guide is used to

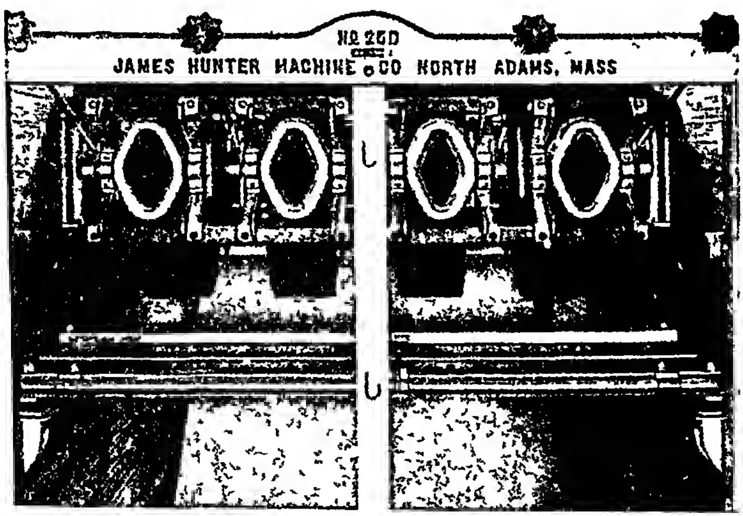


Fig 12 Adjustable diamond eye guide
(*Courtesy James Hunter Machine Co*)

assist the felting in the direction of the filling From here the goods pass into the main fulling rollers, completing the cycle of continuous operation

The pressure given to the top rollers and its proper control is an

important factor in good fulling Up to recent years, pressure was provided through weights and springs, but a late development is the application of hydraulic pressure (Fig 13) This device assists greatly in definite control of pressure and ease of operation

Modern fulling machines are equipped with roller bearings throughout, so adjustments for throats and top roller tensions can be made during operation

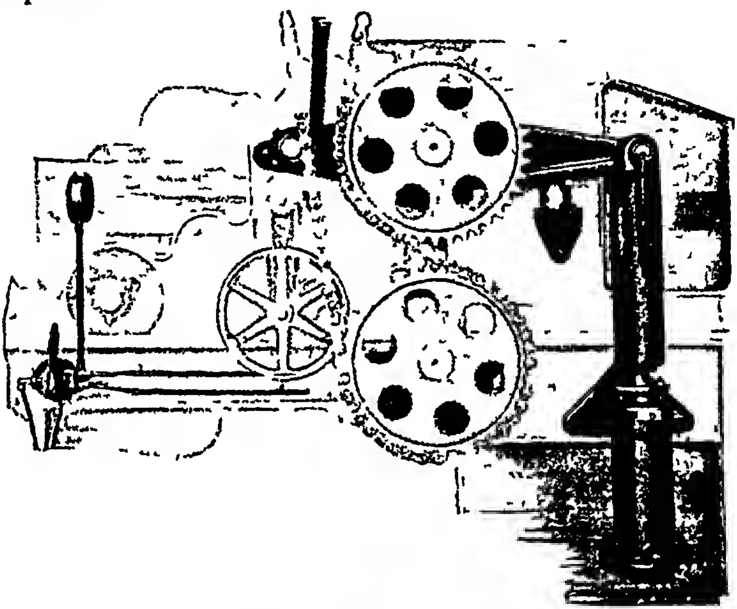


Fig 13 Hydraulic pressure control for top roller
(*Courtesy James Hunter Machine Co*)

In the last few years, more and more machine builders have begun to build fulling machines entirely of stainless steel A new design (Fig 14) has basic changes in the construction of the tub that enable the top part of the machine to be dismantled within a few minutes and the top and bottom rollers to be easily removed Valuable, also, is the additional feature that this machine is supplied with pressure gauges to indicate the pressure not only of the top roller but also of the trap and the adjustable front guides

Continuous rotary fulling mill In the fall of 1946 the development of the first continuous fulling mill was announced The machine, which is illustrated in Fig 15, is a combination of two rotary fulling mills facing each other, but built within one housing Essentially, the

new mill consists of two sets of rollers running continuously in opposite directions The top rollers are mounted on a walking beam and the pressure is applied to them by means of pneumatic cylinders This method of mounting the top rollers eliminates the necessity of reversing the rollers because the cloth will travel only in the direction imparted at the point where the two rollers are brought together; this mounting also allows the cloth to reverse after having been packed into the crimping box The action on the cloth is exactly the same as in a regular rotary fulling mill The operation of the fulling mill is as follows

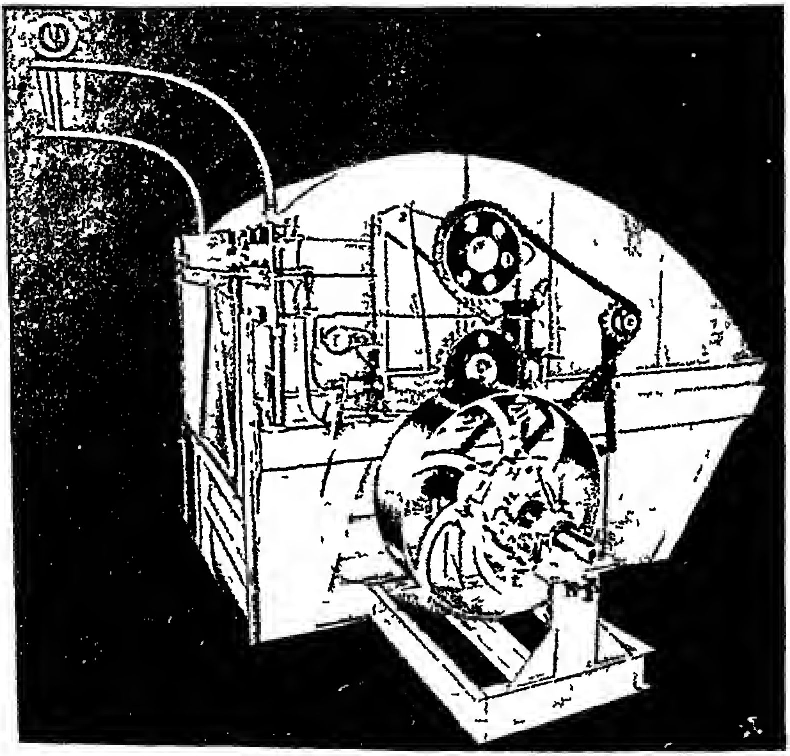
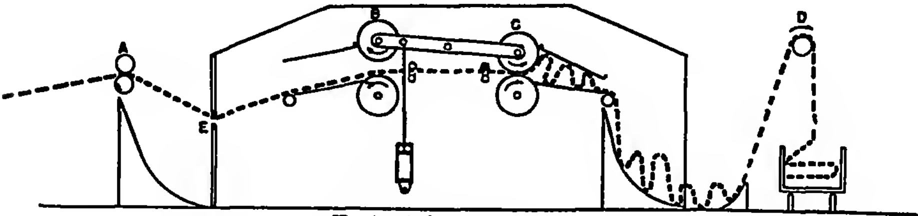
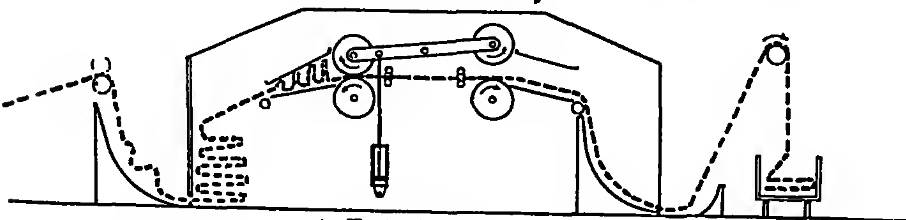


Fig 14 Stainless-steel fulling mill
(*Courtesy Rodney Hunt Machine Co*)

A leader of 15 to 20 yards is kept in the machine, with one end in the scray at the delivery end and the other passing through squeeze rollers *A* (Fig 15) The first piece of cloth is sewed into the leader at the feed end and with rollers *C* together, a full cut of



a End of forward cycle



b End of reverse cycle

FIG 15 Continuous fulling mill (*Courtesy James Hunter Machine Co*)

cloth, for example, 60 yards long, is pulled into the scray at the delivery end of the machine through squeeze rollers *A* and fulling mill rollers *C* Succeeding cuts are sewed onto the end of the first one The cloth is fed through a pot eye *E*, which is capable of moving up and down in guides This eye is so constructed that, as it is raised, it operates a solenoid valve which brings rollers *B* together and sets in motion an automatic timer This timer determines the length of back travel on the cloth

After the cloth is completely in the scray at the delivery end, and the pot eye *E* is at the bottom of the fulling mill, the clutch is thrown in, which immediately raises the pot eye and reverses the setting of the rollers so that the cloth also reverses The pot eye *E* then drops and the automatic timer controlling the reverse is set in motion This allows the machine to run back for the length of the first cut which requires slightly under one-half minute As soon as the cloth is completely fed back, the timer reverses the solenoid valve controlling the pneumatic cylinders and resets itself, then rollers *C* come together and the forward cycle begins This will put out the 60 yards that are in the feed end of the machine, plus whatever has been fed in by the small rollers *A* As soon as all the cloth is out of the feed end of the machine, the pot eye *E* is raised, which again reverses the direction of the rollers and brings rollers *B* together and rollers *C* apart, repeating the cycle The traps are actuated by patented pneumatic cylinders as shown in Fig 15 and as the rollers rise the tongues of the traps also are raised A delivery roller provided at

D takes care of the cloth at the delivery end of the machine, this roller runs at approximately the speed of rollers *A*, depending upon the shrinkage of the goods

The production possibilities of the continuous fulling machine depend upon the number of strings and the fulling time For example, a four-string mill with the cuts 60 yards long, with thirty minutes fulling time, will produce 2 yards per minute on each string or 8 yards on the four strings, in one hour, that is 480 yards or eight cuts, or in 8 hours, sixty-four pieces

The advantages to be gained by the use of the continuous rotary fulling mill in preference to the conventional rotary fulling mill are

1 More uniform fulling and the elimination of the human factor

2 Increased production, because there is no loading and unloading time for each set of goods

3 Fewer chances of mill wrinkles forming in the cloth, because the cloth is reversed and its position under the rollers changed each time it is reversed, which accomplishes the same purpose as taking the pieces out and turning them around by hand as in an ordinary fulling mill

4 No chance of tangling in the mill, because the cloth is always being pulled off the pile at each end rather than from the bottom of the pile as in an ordinary fulling mill

5 Uniformity of fulling on different pieces, whatever the length of the cut In an ordinary mill, if the pieces are not matched up fairly well for length, the longest one receives the least fulling, and it is sometimes necessary to take out the shorter pieces and leave in the longer ones

Tacking In preparation for fulling the cloth is generally *tacked* The goods are doubled over, face in, and the two selvages sewed together by hand or, more commonly, by machine The purpose of tacking is to prevent chafing of the face and to permit *ballooning* of the goods, in this way preventing fulling wrinkles and streaks In cheaper grades of goods, tacking is resorted to for *flocking*, which means felting on *shear flock* for the purpose of adding weight to the goods

Soaping The bulk of goods is run through a soaping machine in open width or string form By this method the soap is uniformly distributed and its amount controlled Various types of soaps are used, such as tallow and palm oil soaps, the high-titer soaps preferred in New England mills It has been proven that low-titer soaps, such as olive and oleic acid soaps, are just as suitable and have

the added advantage of good rinsability They are bought in solid or flake form of 70 or 97 per cent actual soap content Additional soap may be added as needed during the fulling to keep the pieces properly lubricated

The fulling mills can be loaded with goods by one of two methods, single draft or double draft The former consists of running a piece through the fulling roller *single strand*, whereas in the latter the piece is doubled or run *double strand* Single draft is used in qualities where the shrinkage takes place unevenly in width and length In other words, when length shrinkage is desired the width shrinkage is retarded by providing less resistance in the throats or eye guide Double draft is used when a quick felting action in length as well as in width is wanted The amount of shrinkage given by fulling may vary from a few per cent to as high as 30 per cent in length and 15 to 35 per cent in width Fulling shrinkage is controlled by stopping the machine at intervals and measuring width and length by hand or special measuring devices The following example illustrates fulling shrinkage

Army Cloth	*Before fulling*	*After fulling*	*Per cent shrinkage*
Width	80 in	56 in	30
Length	50 yd	38 yds	24

After fulling, the pieces containing the soap and other fulling agents are subjected to a washing process similar to that described under piece scouring In acid fulling, the removal of the acid is accomplished by neutralizing with an alkali and thoroughly rinsing with water

As the fulling process is essentially a shrinking process and is employed to regulate the weight of the fabric, the necessary calculations must be made before fulling The weight of the goods will be materially lessened after the oil, as well as other foreign matter adhering to the fibers, is removed In addition to the wear and tear of the fulling process and the later raising and shearing, a further loss in weight is sustained There is considerable variation among the various fabrics in all of these weight losses and, therefore, a proper estimation of the loss can be attained only by actual trials The percentage of loss varies with the stock or type of raw material used more than with anything else The ultimate finish which the goods receives has a direct bearing on the weight loss

A piece weighing 20 ounces per yard raw should be fulled to 20 ounces per yard finished weight Through scouring and fulling the piece will lose 20 per cent, which is equal to one-fifth, or 4 ounces

per yard Therefore, with no shrinkage at all, the piece would weigh only 16 ounces per yard To make up to this loss, the piece must be shrunk one-fifth in width and length This means one-fifth of 1 yard, or 7 2 inches Therefore, the fuller has to shrink each yard of the goods 7 2 inches to obtain a finished weight of 20 ounces per yard This means that a 60-yard piece would be shrunk to 48 yards For best fulling results it is essential that the contraction in width and length proceed simultaneously

The following defects may be encountered in fulling

1 Streaks along the edge of the piece, resulting from curling selvages

2 Too much friction, from allowing the piece to run too dry or from excessive roller pressure

3 *Fulling rows* or *marks*, from *roping* of pieces, one of the greatest troubles With some goods, a constant shaking out and reversing of the direction of the pieces is necessary

4 Irregular streaks in the cloth, from setting the piece too wide in the loom This also entails prolonged fulling

5 Transverse marks at the end of the piece, caused by uneven seams

6 *Fulling rows,* from the use of very heavy soap, which retards the felting

Carbonizing

The carbonizing process, the underlying principles of which were explained in Chapter 9, has for its principal object the destruction of vegetable matter by means of acids The acid reduces the vegetable matter to carbon, which is removed by mechanical action and the excess acid then neutralized There are four steps involved, namely, steeping in acid, drying and baking, dusting, and neutralizing

As already pointed out, a much greater amount of wool is carbonized in the form of piece goods than in loose form The reasons for this are two-fold *first,* because piece carbonizing is less costly and, *second,* to preserve the full fiber strength through the operations of carding and spinning.

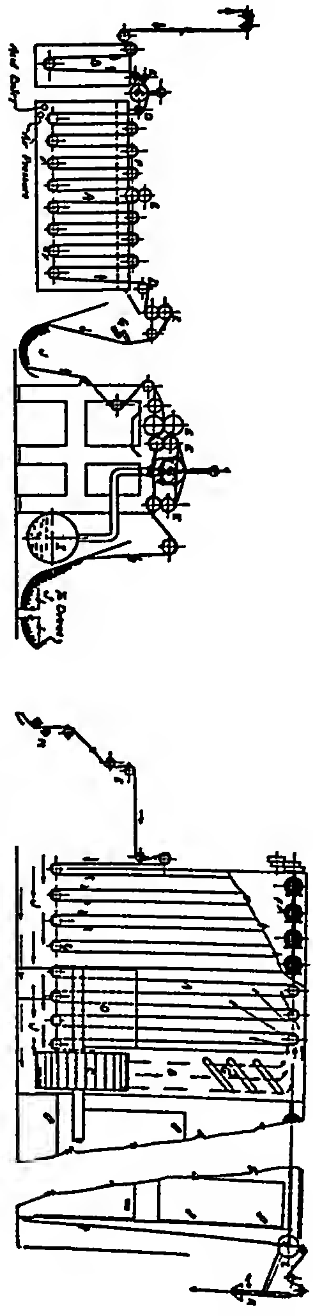
The pieces may come from scouring, fulling, or dyeing, depending on the type of the goods. For example, polo cloths, flannels, and similar goods should be carbonized before fulling, because the removal of large burrs from the face of these goods is apt to leave marks, and spiral burrs are difficult to dust out, even though they may be well carbonized Velours and most worsted fabrics are successfully carbonized after fulling When carbonizing after dyeing,

great care should be taken to avoid changing the shade

Equipment for piece carbonizing has been primitive until recent years The steeping was accomplished by running the goods in rope form over a winch, similar to a piece-dyeing machine The pieces had to be opened, hydro-extracted, and again sewn end to end at full width and passed through the dryer

Today, the steeping and the baking processes are accomplished in one continuous operation that has eliminated many of the troubles encountered in the old method The continuous cloth carbonizing machine generally consists, in sequence, of a wetting-out tank, an acid-soaking tank, a vacuum- or squeeze-roller extractor and a carbonizing dryer The European manufacturers of this type of machine prefer the vacuum extractor, whereas the American builders have shown their preference for the squeeze-roller extractor These two types are illustrated in Figs 16 and 17

A new carbonizer uses the squeeze-roller extraction arrangement shown in Fig 17 The use of squeeze-roller extraction not only eliminates the often troublesome vacuum extractor, with its attendant high horse power requirements, but it offers advantages in the carbonizing operation itself.



A—acid vat C—vacuum
B—wetting-out vat E-F—squeeze rolls
I—waste acid tank

Fig 16 Sectional view of acid tank, vacuum extractor, and carbonizing oven

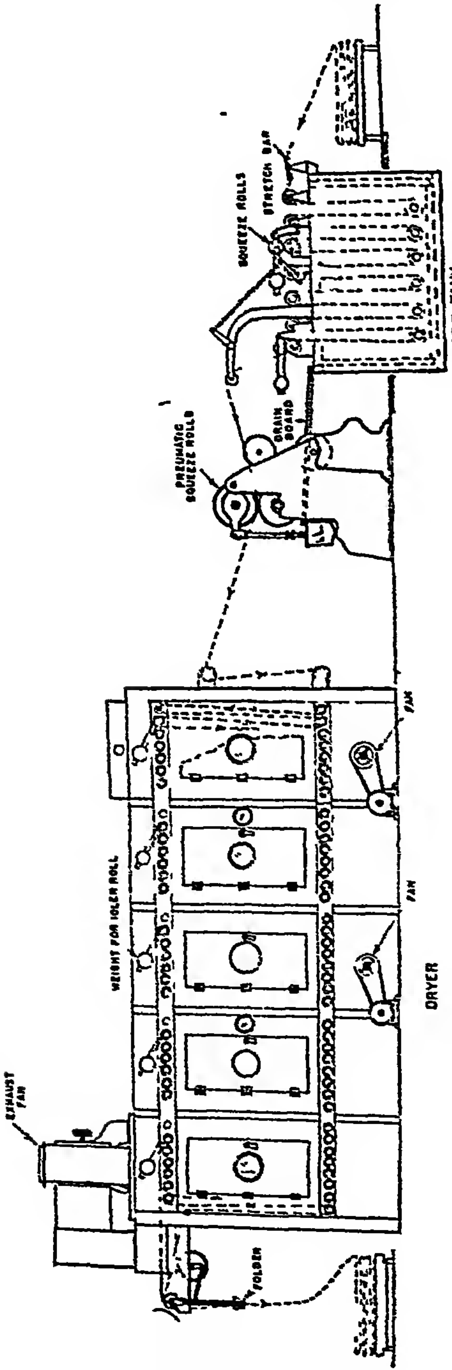


Fig 17 Continuous piece carbonizer *Courtesy James Hunter Machine Co*

Steeping in acid. Assuming the goods are dry, a number of pieces are first sewn together, end to end, at full width to make a continuous chain that enters the wetting-out tank by means of two narrow rubber leaders, one at each side, which are already threaded through the entire machine The object of wetting-out is to obtain uniform moisture content in the goods to permit it to absorb the acid in the next tank equally and uniformly The goods pass over and under a set of top and bottom rollers and then are guided over a vacuum slot that draws out the excess moisture

Whenever goods are delivered in a *wet* condition, the above procedure becomes unnecessary and the goods enter the acid-soaking tank directly. The pieces first pass over a guide roller and a spreader, into a tank filled with diluted acid, then over and under a series of six to eight top and bottom rollers In the center of the tank a pair of squeeze rollers serves to relieve strain as well as to assist the acid to penetrate the cloth by squeezing out the air. At the delivery end of the tank

there are another spreader roller and a large pair of rubber squeeze rollers to remove the excess acid. In European machines the pieces pass over a vacuum slot for final extraction.

The speed of the goods varies. The slowest speed is approximately 5½ to 6 yards per minute, whereas the highest speed may be 35 yards per minute. For medium and heavy weights (from 16 ounces up) the slow speed is required; for light goods a faster speed can be employed. The carbonizing agent is commonly sulfuric acid, which is best stored in a lead tank sunk below the level of the floor. Its normal strength is 66 degrees Bé. This acid is diluted for feeding purposes to a strength of 5 to 6 degrees Bé in a large, separate tank that is at a level above the carbonizer. This diluted acid is now fed to the steeping tank through a lead pipe that reaches to its bottom and has a perforated extension over its full width at the feed end.

The incoming acid is thoroughly mixed with the steeping liquor by compressed air, thus giving a uniform concentration throughout the tank. The actual steeping concentration is determined by the quality of the goods as well as by the amount of vegetable matter present. For light weight fabrics the acid concentration may be as low as 1.5 degrees Bé or, for 30-ounce goods, it may be as high as 4 degrees Bé. Its strength is best controlled automatically by the use of a recording *p*H meter and a micromax controller. The actual immersion time at the low speed with eight pairs of rollers is approximately three minutes. The temperature is always room temperature.

Through the use of heavy squeeze rollers, a uniform as well as a high degree of acid extraction is possible. Under this high pressure, a more thorough acid impregnation of the burr content is also accomplished. In order to reclaim the extracted acid from the cloth and return it to the acid tank for reuse, either a stainless-steel or lead-lined drip pan, which drains directly back into the acid tank by gravity, is mounted under the squeeze rollers, thus eliminating any necessity for pumps.

The extraction of excess acid also may be effected by a vacuum slot or mouthpiece made of acid-resisting metals. There are various types of mouthpieces such as single and triple slots, the most common being the single slot. The ends of the slots may be covered to match the width of the running piece that is electrically controlled at all times to prevent gaps.

Drying and baking. Drying has two distinct functions: to dry the cloth itself and to char the vegetable matter. After the cloth leaves the extractor, it goes directly in open width, free from wrinkles, into the drying and baking section of the unit. To avoid destruction of the piece

numbers it is customary during this process to treat the piece numbers (sewn on the head ends with cotton thread for identification) with an alkaline solution such as 1 part of sodium silicate and 10 parts of six per cent soda solution

The entire drying unit is made up of a series of sections or chambers, the number of which may vary from five to ten In a six-section unit, the first four act as drying and the last two as baking chambers Preheated air enters the chamber through circulating fans, blowing it across the width of the goods and then drawing it down through the fabric An exhaust fan takes care of the removal of the nearly saturated air After the cloth is thoroughly dried, it passes into the baking section, where the greatest heat is applied, usually 190 degrees F or over. Special care is taken that the hot-air circulation maintains a uniform temperature throughout and at all times The pieces leave the baking section at the top of the machine and are folded into a truck The temperatures maintained in a unit of six sections are given in Table 1

TABLE 1 TEMPERATURE RANGES IN CARBONIZING

Chamber	*I*	*II*	*III*	*IV*	*V*	*VI*
Degrees F min	120°	145°	160°	175°	190°	200°
Degrees F max	145°	160°	175°	190°	200°	210°

The rate at which the goods passes through the drying unit is dependent on the speed permissible in the immersion tank. The rate

Fig 18 Carbonizer dryer Feed end of 10-section continuous carbonizing unit. *Courtesy James Hunter Machine Co*

in the immersion tank is kept slightly lower than the rate in the drying unit to avoid the possibility of stretching or breaking the pieces between the sections

A special compensating range drive that eliminates undue tension and building up of slackness in the dryer has been developed This drive holds a predetermined tension on the cloth from the time it enters the unit until it leaves The control is split into sections, and the tension in all sections may be set alike or it may be adjusted to give more or less tension in different sections The time varies with the number of chambers, for a six-chamber oven it is approximately one-half hour, of which about one-third is devoted to the baking

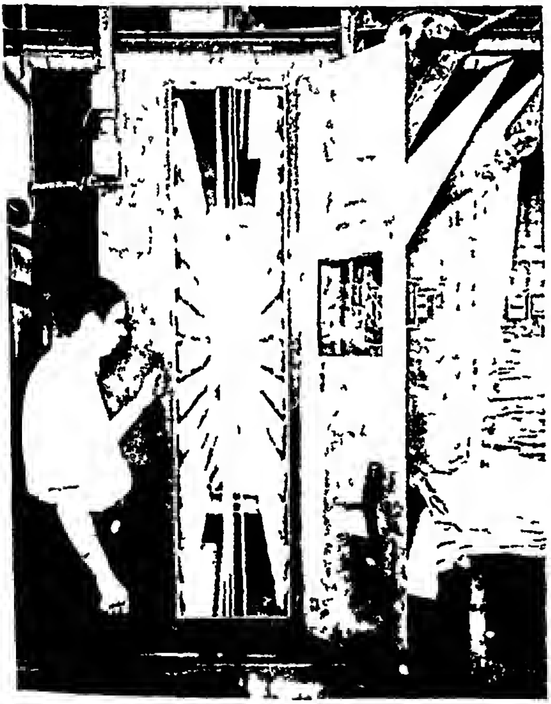


Fig 19 Infrared baking unit (*Courtesy Riggs & Lombard*)

Infrared drying. A new development is the application of infrared rays for the final baking One type of infrared baking unit follows the last section of the dryer The heating equipment consists of two banks of infrared lamps facing each other (Fig 19)

Cloth is fed from the dryer into the baker under a roller at the bottom and then vertically upward to the top, where it passes over a roller, then vertically downward to a third roller, after which the cloth repeats this cycle upward and downward over the fourth and fifth rollers and passes under a sixth roller and vertically upward and out of the carbonizer By this means one side of the cloth is exposed to one bank of lamps and the other side of the cloth to the secord bank of lamps The baker has a capacity of 21 yards of cloth At the normal speed of 25 yards per minute each side of the cloth is exposed to the direct rays of the lamps for about twenty seconds

The main advantages of the use of infrared heat for the final baking are said to be two a lower number of drying sections, with consequently less floor space required, and increased production as the speed can be boosted 30 to 40 per cent This is made possible by using the drying and baking section of the dryer for drying only and doing the baking with the infrared unit

Dusting The object of dusting is to crush and beat out the charred vegetable matter from the fabric This is accomplished by mechanical means in a fulling mill Instead of running the pieces with soap, they are run dry and subjected to the crushing of the fulling rollers For economical reasons it is advisable to use a number of dry mills in series The time of dusting varies from five to fifteen minutes, depending on the amount of charred matter to be removed Loosely woven goods, lightweight pieces and qualities such as boucles, which are easily damaged, are not dusted at all The process of dusting is most effective when the goods are dry and hot The wool regains nearly all of its normal moisture in approximately one hour, hence no time should be lost in doing the dusting. The pieces leave the dry mill in rope form and are opened by running them through a mechanical opener or by hand

Neutralizing The object of neutralizing is to remove all traces of acid in order to eliminate difficulties in later processing as well as tendering of the goods For this purpose the goods are treated either in a string washer or a broad washer with a solution of sodium carbonate or soda ash The process is accomplished in three steps preliminary rinsing, alkaline treatment and final rinsing

The purpose of preliminary rinsing is to reduce the acid content of the goods by a spray of water or by floating the goods in a full trough of water This effects a saving in soda ash and eliminates any danger of damage to the material that might occur from the heat of reaction if soda ash were added directly The acid content of the goods should be reduced to about 3 per cent or less in this rinse, which requires about 20 to 30 minutes in a string washer (four pieces).

After this preliminary rinse the machine is drained and the proper quantity of soda solution added The strength of the alkaline bath should be about 2½ per cent The goods are run in this bath until completely neutralized and alkaline to methyl orange The running time depends on the acid content and on the weight of the goods, but is normally from 20 to 30 minutes

The final rinse, which is necessary to get rid of all excess soda, is done by turning on the cold water full force and running the goods continuously for a period of 20 to 30 minutes. On stock- or yarn-dyed goods and color mixtures it is advisable after the final rinse to run the goods for 10 minutes in a weak acetic acid bath for brightening of the colors that are apt to be dulled by the soda A quart of acetic acid (28 per cent) for each two pieces is sufficient Data on neutralization of a coating material weighing 20 ounces (56 inches) is given in Table 2

TABLE 2 NEUTRALIZING PROCESS

Items	*Carbonization*	*Pre-rinse*	*Soda*	*Final rinse*
Running time	—	30 min	20 min	30 min
pH of goods	1 8	2 4	10 6	7 5
Per cent H_2SO_4	6 0	2 8	—	—
Per cent soda	—	—	1 5	0 6

Continuous neutralizing The continuous washer lends itself to the successful application of continuous neutralization In one plant, the soaper and bowls 1 and 2 of the wash section are used for preliminary rinsing, wash bowls 3 and 4 are used as neutralizers, and the reverse-rinse section is used for the final rinse The sulfuric acid content of the carbonized cloths was reduced from 6 to 2 2 per cent in the three-bowl, preliminary-rinse system—employing separate overflows for waste in each bowl, this is equal to an acid reduction of 63 per cent A sodium carbonate solution of 2 per cent strength was found to be necessary to neutralize qualities up to 20 ounces, inactivating all of the residual sulfuric acid and leaving a surplus of approximately 2 per cent alkali in the cloth The back-and-forth motion imparted to the cloth in the reverse-rinse section removed the excess alkali, reducing its concentration to less than 1 per cent, with the *p*H of the final cloth being 8 4 or less The alkali concentration must be controlled by titration The total neutralizing time in the continuous washer, operating at a speed of 40 yards per minute, is approximately twenty-two minutes, which is less than one-third of the normal neutralizing time necessary in the dolly washer The preliminary rinsing time, with the inclusion of the soaper, amounts to five minutes, actual neutralizing time to four minutes, and final rinsing to thirteen minutes This is possible because there are six nips per minute in the continuous washer as compared to three nips per minute in the dolly washer

Piece-dyed fabrics, which are carbonized after dyeing, are given only a water rinse To avoid stripping of colors, soda has to be omitted Aluminum chloride is not used extensively in piece carbonizing, although it may have its place for carbonizing of stock- or top-dyed fabrics on which dyestuffs sensitive to sulfuric acid are used

Scutching

In most of the wet processes described so far, scouring, fulling, and neutralizing, the pieces are handled in string or rope form. In many instances the pieces are tacked As the proper examination of pieces in rope form is not possible and because most of the operations that follow require that the fabric be in the full width, detacking and opening operations are necessary In small mills these operations are performed by hand and in the larger mills by running the pieces through a scutcher An arrangement for scutching, combined with detacking, is shown in Fig 20 The continuous washer is generally connected directly with a scutcher

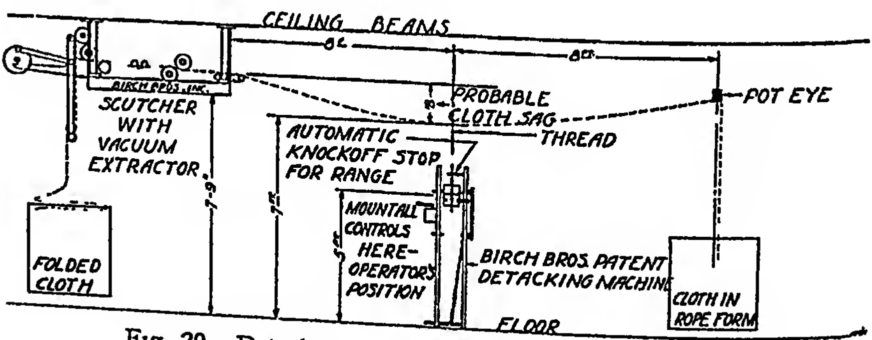


Fig 20 Detacking, opening, extracting, and folding (*Courtesy Birch Brothers, Inc*)

Beaming, Wet Decating, and Blowing

Beaming Face-finished goods coming from scouring, fulling or carbonizing, contain many creases and wrinkles that require removal before napping or gigging Creases can be removed by two methods, beaming or wet decating, choice of which depends on the type of the cloth and the severity of the creases The easiest method is beaming, which is a simplified form of crabbing The goods are run through warm or hot water depending on whether the fabrics are stock dyed,

yarn dyed or piece dyed In beaming, the temperature is kept between 120 and 140 degrees F., whereas in wet decating the temperature may be raised to 170 degrees F. The goods are wound tightly on a wooden roller with a heavy pressure roller on top, and then run for half an hour. English crabbing machines, when available, are used for this purpose.

Wet decating. Where a more permanent setting of the fibers is required and at the same time a certain amount of luster has to be developed, the finisher will apply wet decating, also known as boiling or potting Wet decating is accomplished by the combined application of heat moisture and tension The production of luster is partly attributable to the straightening and leveling out of the surface and partly to the natural luster of the stock itself For example, mohair with a high original luster, needs little decating, whereas fine merino wools require considerable decating to produce a similar luster

There are various types of decating machines (Fig 21), all of which have the following essential features a metal trough containing several perforated metal cylinders to allow water or steam to circulate freely, a pump for this circulation, and a suitable tension arrangement

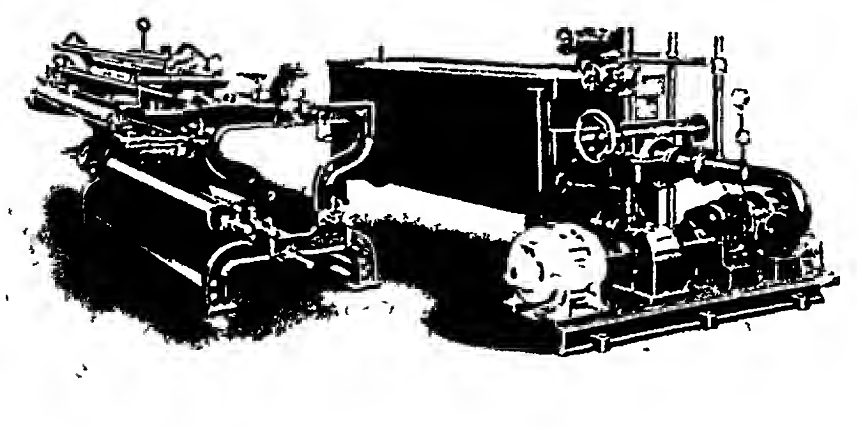


Fig 21 Wet-decating unit (*Courtesy David Gessner Co*)

Blowing In the preparation of the cloth for wet decating or blowing, cotton leaders are stitched to each end of the fabric, which is then wound in a suitable state of tension on a perforated metal cyl-

inder Thus, the cotton leaders become the interior and the exterior layers of the roll, not only protecting the cloth during treatment, but also ensuring even penetration of the water and steam throughout the roll After being bound with heavy cotton tape, the cylinder surrounded by the roll of cloth is placed in the trough The piece is then treated for five to twenty minutes at temperatures ranging from 140 degrees F to boiling with water circulating in both directions, or it is blown with steam from the inside of the roll for five to ten minutes The effects of the treatment can be considerably increased by the combined use of hot water and steam. However, such a treatment carries with it the danger of severe fiber damage The cooling of the cloth is accomplished by drawing cold water or cold air through the roll by means of a vacuum pump

Raising

As the name implies, the raising process consists of lifting out from the body of the fabric to the surface a layer of fibers which has been developed in fulling or from the yarn itself This layer of fibers is variously termed nap, pile, or cover Raising is distinctly a mechanical operation The action is simply to entangle the fibers with the sharp points of teasels or wire rollers and to bring the fibers to the surface of the fabric Four objects of the raising process are

1 To produce a nap, pile or cover on the surface of the cloth
2 To secure softness and a lofty handle
3 To conceal the weave or design, to soften the outline of the pattern and partially to blend the colors
4. To promote a more thorough felting as a preliminary to the fulling process.

The raising operation may be accomplished by means of teasels (gigging or teaseling) and by wire-covered rollers (napping) There are four principal systems of raising the nap when submitted to the action of the teasels or wire-covered rollers, moist gigging and wet gigging, moist napping and dry napping

Gigging or teaseling Gigging is done with teasels which are the dried flower heads of a species of thistle plant grown and cultivated specifically for this purpose in the state of Oregon and in the vicinity of Schenectady, N Y The largest cultivation of teasels is in southern France, where there is a large-size teasel, known as the king teasel, which is about 2 inches in length The medium-size teasels are 1½ to 1¾ inches long and are the most expensive. They are set into the frames as tightly as possible in two or three rows (Fig 22) For proper setting they are pre-treated with hot water or steam for

five minutes to soften them and then allowed to dry These frames or iron slats are then mounted on a drum This drum rotates at a speed of 100 rpm and the cloth is brought into direct contact with the teasel-filled slats It is very important that the raising of the fibers be done very gradually *so that the fibers are not torn out*. They are merely untangled and lifted Therefore, the teaseling process should begin with used teasels, the points of which have already been dulled and softened Gradually new or sharp teasels are employed until the desired nap or pile is developed.

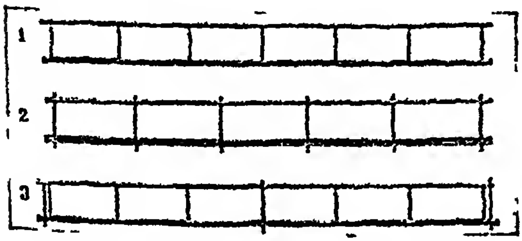


Fig 22 Three types of teasel slats

Moist gigging and wet gigging Of these, moist gigging is the most general method The raising of the fibers is done in the moist state followed by the process of wet gigging, in which the cloth runs saturated with water Wet gigging really should not be considered a raising process In this action the fibers that were raised in moist gigging are laid down in one direction on the surface of the cloth In the moist and the wet gigging processes the fibers are swollen and their elasticity and rigidity are diminished Consequently, they are more pliable to mechanical stress This raising process is generally applied to broadcloth finishes, where an evenly laid down nap with a lustrous appearance is desired

Figure 23 shows a one-cylinder, four-contact gig Specially designed for wet gigging, it is made with a skeleton iron or a wooden cylinder into which the teasel slats are set in rows The slats are staggered 2 inches by pairs and 20 or more are required for a cylinder The number of teasels required to fill twenty slats varies from 2500 of the 2-inch teasel to 4000 of the 1½-inch teasel

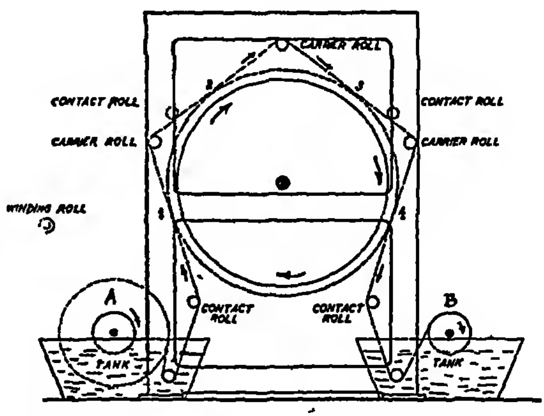


Fig 23 One-cylinder four-contact gig
(*Courtesy Curtis & Marble Machine Co.*)

The goods are wound in full width on roller *A*, submerged in a trough of watei from which they are unrolled by means of a leader, passed over the contact and the carrier rollers around the cylinder of the gig, and rerolled on roller *B*, also submerged in a trough of water The cloth contacts the teasels at points *1, 2, 3* and *4*

The direction of rotation of the cylinder is the same as that of the cloth, but it runs at a higher speed When all the goods have been unwound and the second leader comes up, the machine and the cloth are reversed, this being continued until a good nap has been produced The contact rollers are adjustable and, if set closer to the cylinder, they give a greater gigging action, producing a greater amount of nap

During the gigging process the teasels become filled with wool fibers and lose strength because they are wet To restore them to use, they are dried and brushed clean by hand or with a brushing machine

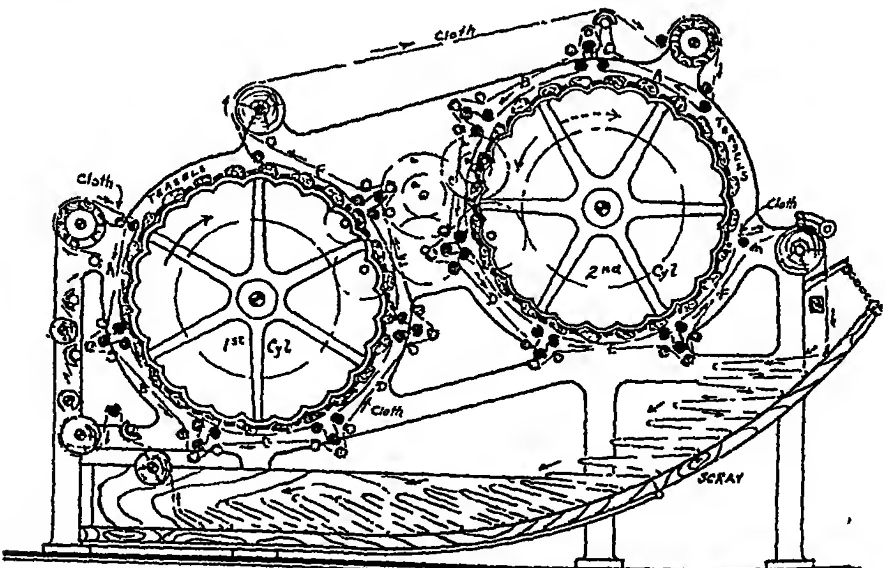


Fig 24 Double-cylinder, twelve-contact teasel gig (*Courtesy A Suter*)

Double-cylinder gigs and also "rolling" teasel gigs have been built to overcome some of the drawbacks, such as low production and reversing cylinders, of the old "up-and-down" gig Also the number of contacts has been increased from four to six, which in a two-

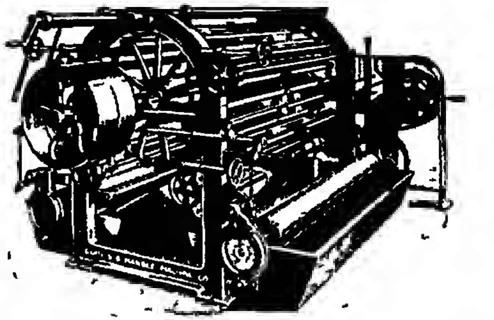


Fig 25 Four-contact gig with water box for wet gigging
(*Courtesy Curtis & Marble Machine Co*)

cylinder gig amounts to twelve contacts (Fig 24) Instead of cloth rollers, scrays are used to enable continuous gigging of a greater number of pieces in a long chain. The cloth speed is 8 to 10 yards per minute The number of runs depends on the surface of the cloth and the character of the yarn

Instead of teasel slats, the cylinder may be fitted with brush lags set with any grade of bristle, hair, or fiber and used for wet or damp brushing on face-finish goods

Napping. It is now more than a century since attempts were made to employ fine steel wires in the raising process and today there are wire napping machines which give fast production and are so constructed that the raising of the wool fibers can be done very gradually These processes are carried out by means of fine steel wires, called

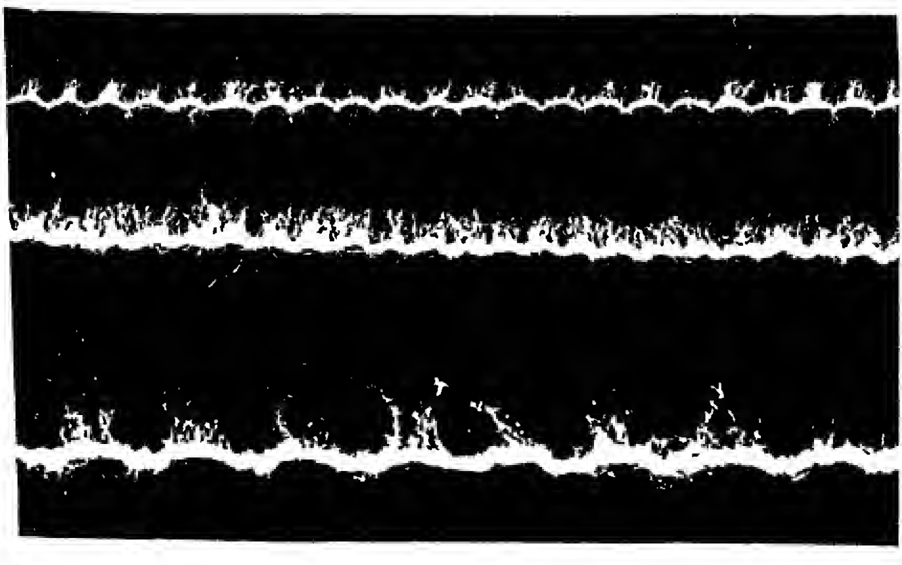


Fig 26 Types of naps suede, duvetyn, velour top to bottom

wire card clothing, that are generally applied to fabrics where a dense lofty nap is required The fibers, in contrast to the laid-down nap, are lifted with the sharp points of the steel wire and kept in a nearly upright position This produces a finish on woolen cloth similar to that on velvets and plushes, where the pile is formed by cutting the yarns. (See Chapter 21)

Moist napping is usually a preliminary process to the succeeding moist gigging In general, it is applied to fulled fabrics where the fibers have formed a dense layer of felt on the surface The action of the wire points is more drastic in its nature than the teasel points and the entanglement of the fibers is more efficient

Dry napping is more suitable for fabrics which are not fulled. The raising of the fibers must be done from the warp and the filling threads, and hence produces a spongy, lofty pile

The amount of napping or gigging applied to fabrics depends on the quality of the goods The raw material used, the structure of the weave, and the weight and strength of the fabric are factors to be considered.

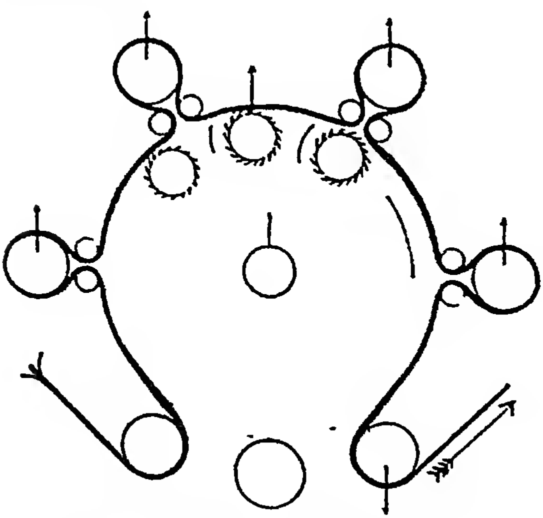
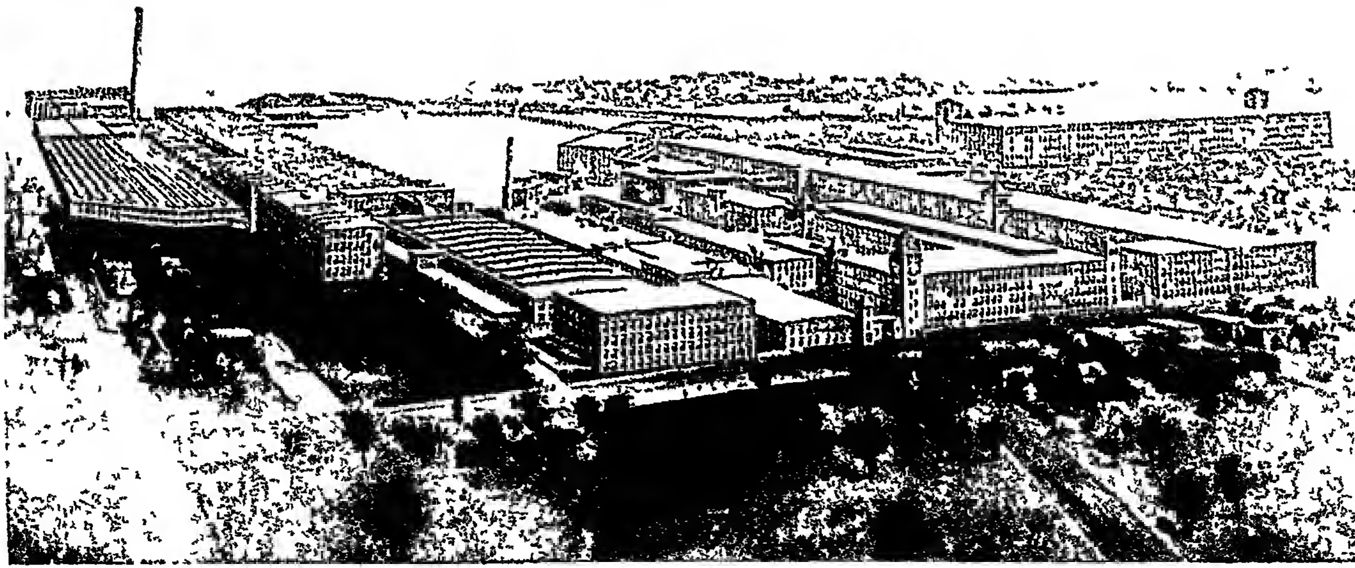


Fig 27 Diagram of single-acting napper

There are two types of nappers, i. e, single acting and double acting In the single-acting machine, also called the French or straight-away napper, the nap rises in one direction only. The cylinder runs in the direction of the goods at a fixed speed, of 100 r p m. On its periphery are small wire rollers that rotate on their own axis at an independent and variable speed in the opposite direction of the cylinder

The cloth runs through the machine in the same direction in which the cylinder rotates, the points of the card wire are carried into the cloth by the forward rotation of the cylinder, the degree being determined by varying the speed of the wire rollers (Fig 27)



Arlington Mills, where wool is scoured by the solvent process

Extracting

A woolen fabric at room temperature at 100 per cent relative humidity can absorb approximately 26 per cent water vapor calculated on a wet basis (moisture content), or 35 per cent on a dry basis (moisture regain) Any water above this figure is present as fine droplets in the fiber interstices and can, therefore, be removed by mechanical extraction Three types of machines are used

1 *Squeezer or wringer* Until recently the squeezer was the least effective of the three machines However, the newest type of squeeze rolls can reduce the moisture content to as low as 38 per cent, or 61 per cent moisture regain, almost the maximum in efficiency. The pressure of this machine is hydraulically or air controlled The squeezer illustrated in Fig. 1 is air controlled and, in addition, is equipped with a dial gauge and an automatic safety valve. The dial regulating valve shows the exact roll pressure at all times, thus ensuring proper control during this operation Pneumatic controls cushioned against momentarily greatly reduced pressure when the seams or bunches pass through the rolls keep the pressure on the material uniform at all times and at all points across the width of the roll Today there is a tendency toward replacing centrifuges and vacuum extractors with the new types of squeezer or roller, because the latter are highly efficient

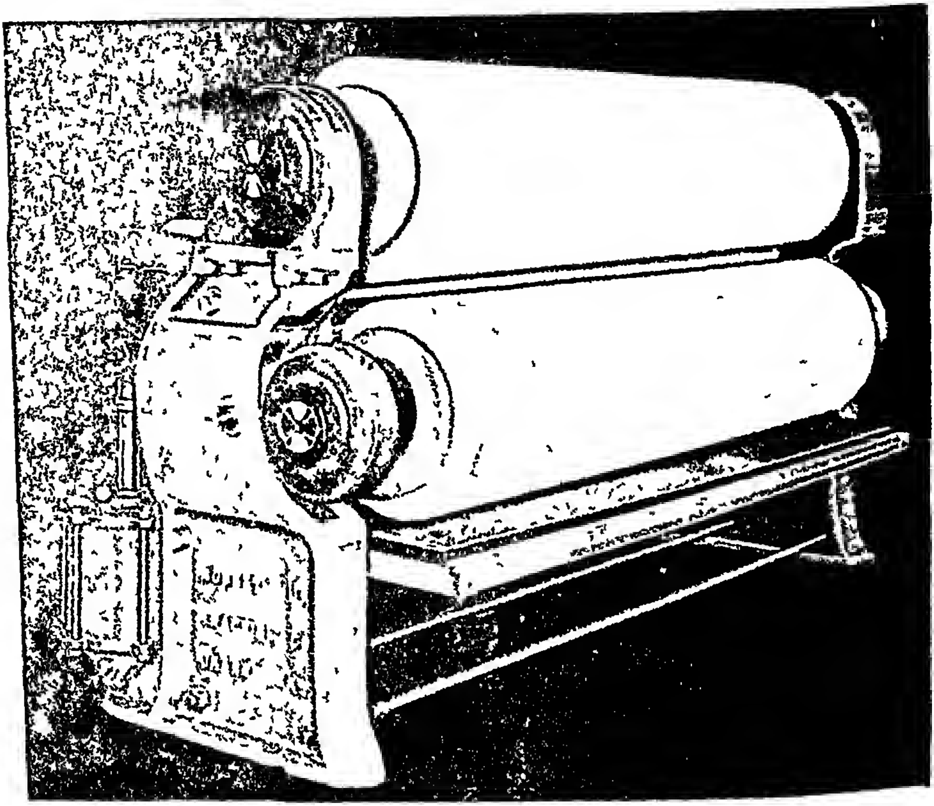


Fig 1 Wring-Master extraction squeezer (*Courtesy Rodney Hunt*)

2 *Hydro-extractor, or centrifuge* The excess water is removed from the cloth by centrifugal force The machine consists primarily of a perforated copper or galvanized iron cage or basket built around a central spindle, the whole being encased in strong cast iron or steel The spindle is rotated at a speed up to 1000 r.p m, developing centrifugal force which is resisted by the inner surface of the cage This causes a pressure on the cloth in the cage and forces the excess water through the perforations in the sides to the casing, where it is drained away There are various methods of driving the drum, belt drive, friction drive, and direct drive with a built-in electric motor The speed of the basket varies with its diameter

36-inch diameter—1000 revolutions per minute
48-inch diameter— 900 revolutions per minute
60-inch diameter— 750 revolutions per minute
72-inch diameter— 600 revolutions per minute

The time required for hydro-extracting depends upon the speed of the spindle and the diameter of the drum (which give the centrifugal acceleration of the machine), and upon the length, weight, and thickness of the cloth, the latter three factors are responsible for any resistance to the centrifugal action Maximum extraction with this method is about 30 per cent moisture content, a figure which is only slightly higher than the theoretical limit of 26 per cent moisture content This limit is generally reached after two to ten minutes, depending on the type of cloth and the load of the machine The advantage of the hydro-extractor over the squeezing machine is that the material is placed in the machine in a loose and free condition without pressure, and there is less danger of wrinkling or of pulling the cloth out of shape. Its disadvantage is that it is a batch process which makes production time-consuming and therefore costly

3 Vacuum extractor In the vacuum extractor the cloth is treated in full width The machine consists of a cylindrically shaped housing with a narrow slot on the top, extending from end to end, over which the cloth passes Connected with the housing is a vacuum pump

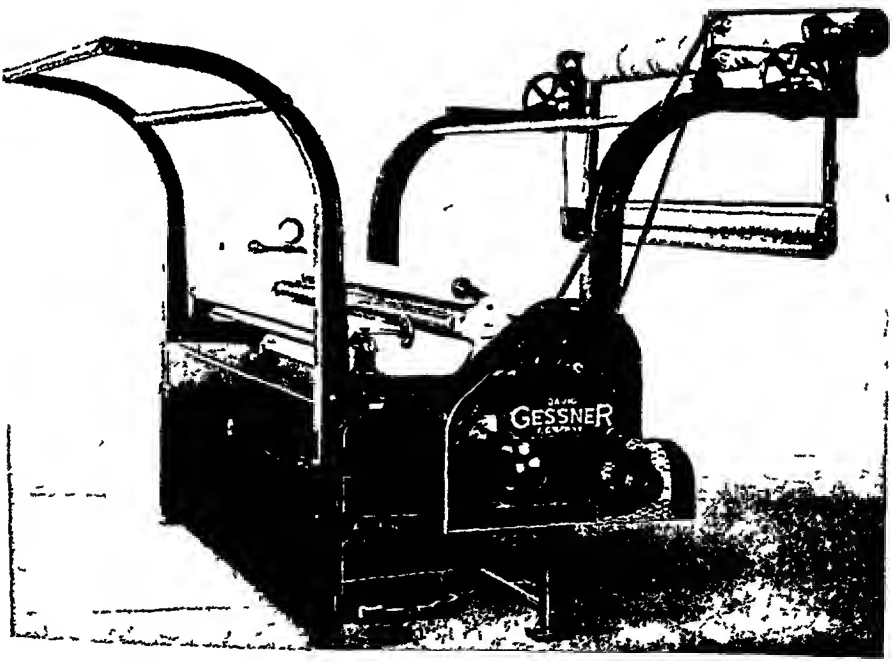


Fig 2 Vacuum extractor (*Courtesy David Gessner Co*)

that draws air from the atmosphere through the wet cloth as it is drawn over the slot, thus forcing the water out Of the three drying machines the vacuum extractor has the lowest efficiency. Generally the moisture content of the cloth after vacuum extraction is about 40 to 50 per cent, corresponding to 67 per cent moisture regain. With lightweight fabrics, a heavy felt or rubber cover is placed on top of the cloth while it passes over the vacuum slot This helps to create sufficient vacuum With thick and heavy qualities, covering of the slot is unnecessary as the tightness of the fabric gives enough resistance to the vacuum. The advantage of this machine is the minimum of disturbance which the cloth receives The disadvantage is the danger of clogging, necessitating frequent cleaning A vacuum extractor is shown in Fig 2

Drying or Tentering

Drying was originally done in the open air. The cloth was stretched by hand between two sets of parallel bars fixed on vertical posts, and held in position by tenter pins A further development was the "tenter house," in which the cloth was dried indoors by hot air. The tenter frames were placed in long narrow rooms heated by steam pipes Today cloth drying is an automatic process carried out by means of various tentering machines which perform the double purpose of drying and stretching. The principal feature of a tentering machine is a pair of endless traveling chains, carried on tracks, on which fine pins are mounted As the cloth enters the machine, it is engaged in the selvages by these pins The machine is built in stories, the cloth-carrying chains passing over sprocket wheels at the end of each story to the next lower level The piece enters the machine from a platform, passing between tension bars to the pins A small brush wheel placed over each chain presses the selvages onto the pins and the cloth is carried from the top story through the whole series to the lower story, where it is released from the pins and delivered by ordinary folding motion Tin cylinders support the cloth at each end of the stories The distance between the two chains is adjustable so that the cloth can be brought to the desired width Wrinkles and creases are pulled out evenly and the warp and the filling are put into the proper geometric relationship.

~~The latest~~ device for automatically feeding the fabric onto the pins of the chains, and at the same time controlling the width, is electrical The cloth is picked up by two electric feelers, and, according to the contact made, moves the chain arms in or out to accommodate its

width This provides for accurate and consistent feeding to the pins which hold the cloth at the selvages (Fig 3)

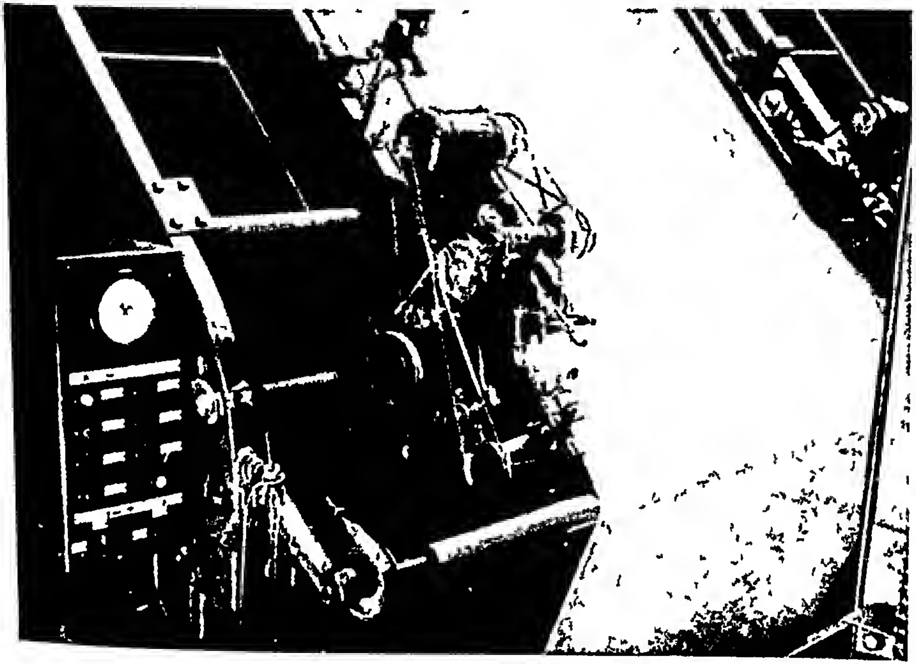


Fig 3 Electrical feeding mechanism for dryers (*Forstmann Woolen Co*)

Machine drying is done by two distinct systems, the first and older by means of radiation of heat from steam pipes, the second and newer by means of hot air blown through the cloth

In the older drying system 1-inch steam pipes or coils are placed in layers between the stories so that the cloth travels over and under each layer, and the heated air radiated from them vaporizes the moisture contained in the cloth A disadvantage of this system is that the heat in the different stories cannot be easily controlled so that the heat is liable to affect the wool fibers and the colors. The joints of the coils are liable to leak and the escaping water and steam may stain the fabric With this system a high temperature is required which must be maintained because no provision is made for the removal of moisture-laden air The result is that a great amount of heat is wasted by radiation through the top and the sides of the machine Drying at a high temperature also imparts a harsh handle to the cloth

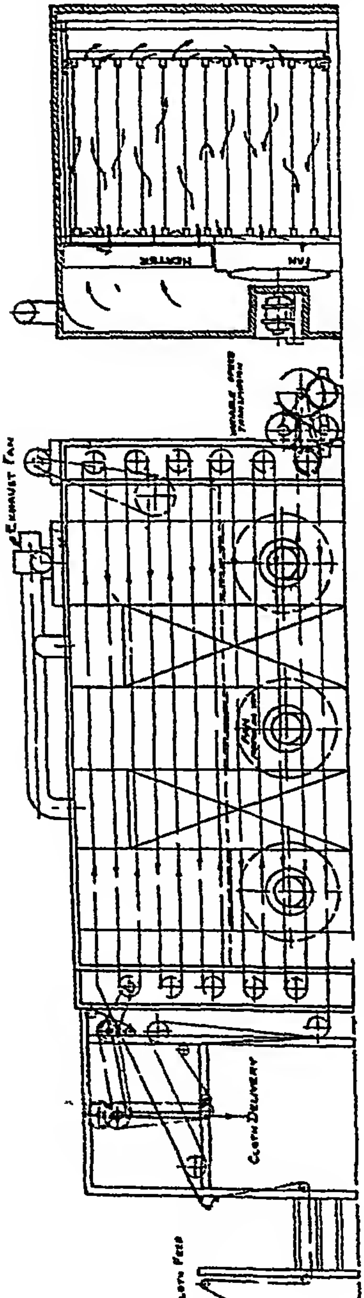


Fig 4 Side and end elevation of Hurricane high-speed tenter or cloth dryer (*Philadelphia Drying Machine Co*)

In the modern drying system (Fig 4) the air which circulates through the cloth is forced through each story by means of fans One fan takes care of the air circulation for two stories Heating elements are installed on the side of the machine where the fans are located The fans suck the air from the outside atmosphere through the heating elements where the air is heated and forced ahead across the cloth into the next story This is repeated until the air has passed the six stories On top of the machine two exhaust fans are provided which remove the excess of moisture-saturated air. By this system the highest temperature in the machine, about 180 degrees F, is at the top where the moist cloth enters In each story the temperature is reduced about 20 degrees so that the cloth, when it leaves the drying machine, is about at room temperature

The dryer is equipped with a speed regulator so that the drying can be varied according to the weight and moisture content of the fabric The steam consumption is 1 6 pounds of steam to evaporate 1 pound of water Cloth weighing 16 ounces per yard can be dried at a linear speed of 35 to 40 yards per minute, providing the moisture content is not higher than 50 per cent

To calculate the steam consumption per piece, reference can

be made to the chart, Fig 5, which shows the number of pounds of water which must be evaporated by drying from fabrics having an initial moisture content of between 35 and 48 per cent in order that

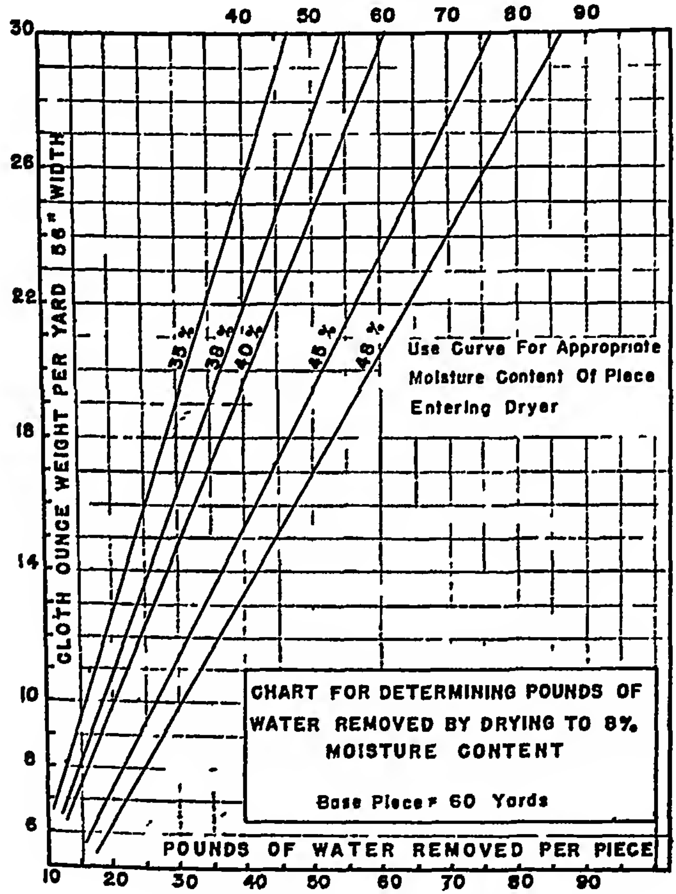


Fig 5 Moisture evaporation chart

they may leave the dryer with a moisture content of 8 per cent For example, a 60-yard piece weighing 16 ounces per yard and having a moisture content of 48 per cent would contain an excess of 48 pounds of water As 1 6 pounds of steam are required to evaporate 1 pound of water, the total amount of steam required per piece would be 1 6 x 48, or 76 8 pounds If the same piece should enter the dryer with

a moisture content of 35 per cent, only 25 pounds of water per piece would have to be evaporated The steam consumption would be 1 6 x 25, or 40 pounds, a saving of 47 9 per cent

Contrary to popular opinion, research has shown that when cloth is exposed to a high temperature when wet, more damage is done than when a cloth is exposed to a high temperature when it is nearly dry The latter method of drying has been used for years in the carbonizing dryer To cool the cloth and to provide it with the necessary amount of moisture, damp air is drawn through the bottom chambers, which have a relative humidity sufficiently high to provide a final moisture content of between 8 and 10 per cent This method of drying unquestionably simulates outside drying conditions more closely than any other A few manufacturers have led the way in incorporating this principle in their regular dryers (Fig 6) Three factors must be considered in drying

1 The moisture-absorbing property of air is increased by raising the temperature

2 The dry air must be brought into contact with the material

3 After acting on the cloth, the moisture-laden air must be removed continuously in order to admit fresh, dry air

Another means of drying cloth is the use of steam-heated drums or cans in various sizes combined with a machine which is called a cylinder-drying machine or felt calender The main cylinder has a diameter of 6 to 8 feet and carries on its surface an endless felt In drying, the cloth is brought between the felt and the surface of the

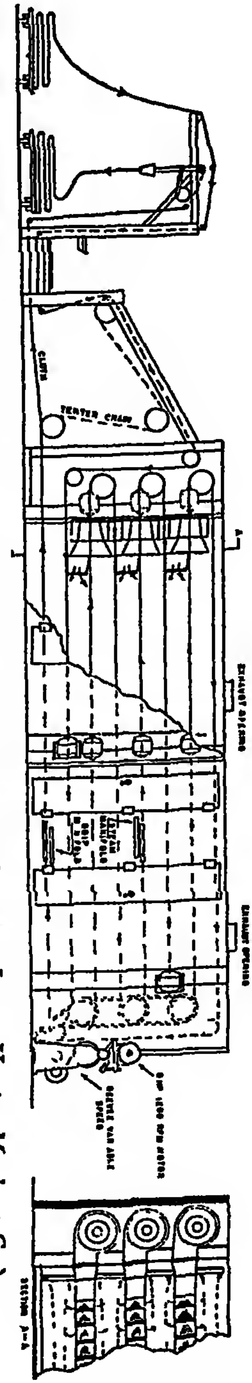


Fig 6 Side and section elevation—8-pass uniflow tenter drier (*Courtesy James Hunter Machine Co*)

cylinder A spreader called a "Palmer," where the cloth can be brought to the desired width, is built in front of this machine Smaller drums, about 2 feet in diameter, are usually arranged in front of the large cylinder and used for predrying The smaller drums, numbering from two to ten, evaporate part of the moisture content of the cloth before it reaches the large cylinder This method of drying is used on very light and cheaper grades of woolen cloths and very frequently on cotton, silk, and rayon cloths

Shearing

The object of shearing is to cut away completely or to even out or level the fiber pile or nap which has previously been raised The amount of fibers to be cut from the surface of the cloth depends on the type of finish desired This dry-finishing operation is used on all woolen and worsted goods.

In *singeing, the hairy surface was cleaned off, but in subsequent* wet processes, additional fibers which were raised through manipulation can now be removed only by shearing Another singeing would affect the handle of the goods and create an odor which would have to be removed by another wet treatment

The general aim of shearing is to clear the surface of the cloth of surplus fibers and thereby bring out certain characteristics such

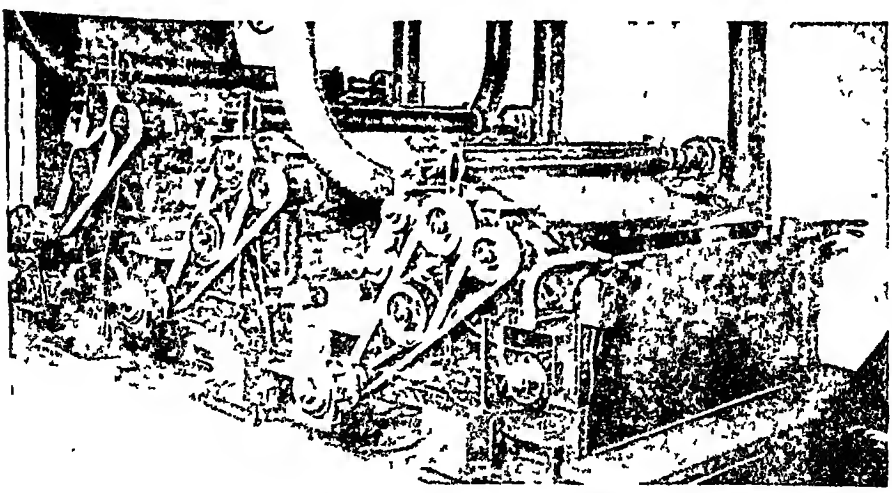


Fig 6 Three-plate automatic shearing machine
(*Courtesy Parks & Woolson Machine Co*)

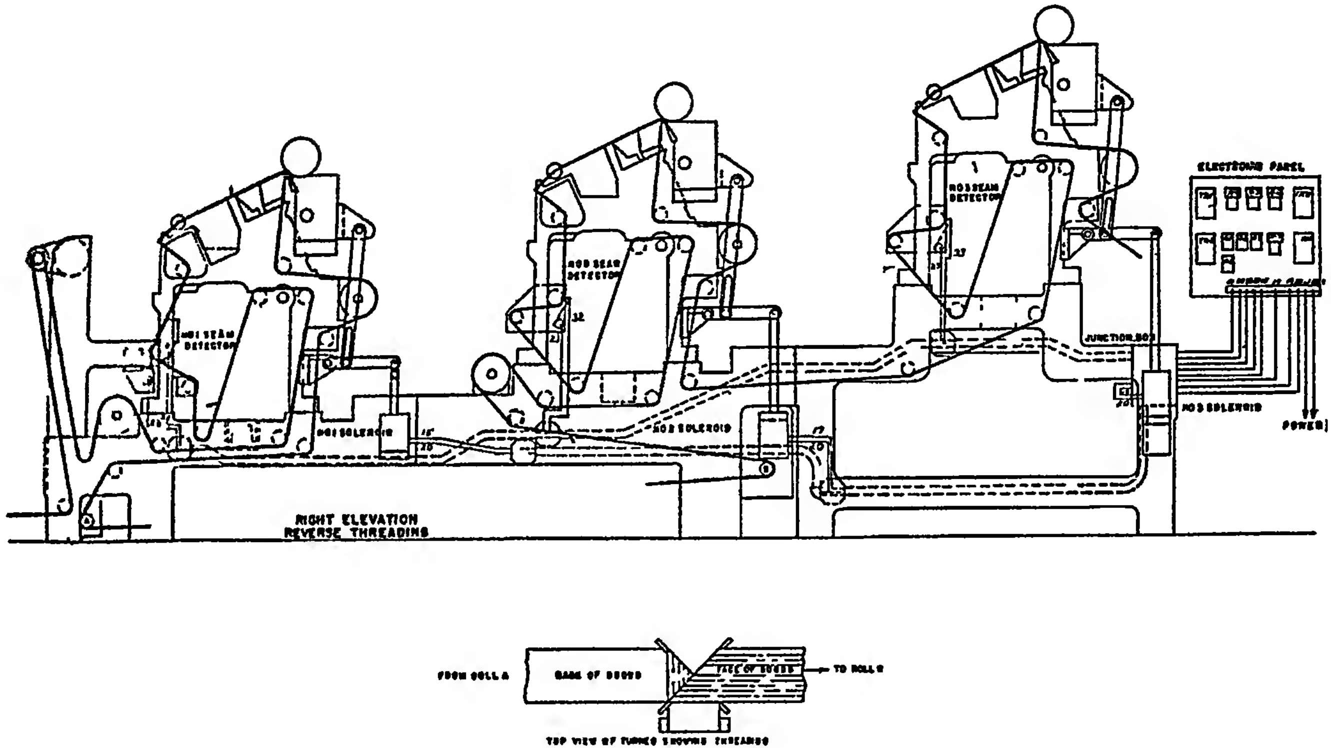


Fig 7. Diagram of three-plate automatic shearing machine shown in Fig 6

Courtesy Parks and Woolson Machine Company.

as the design or color pattern The most drastic shearing is done on fabrics which require a clear face, such as gabardines and serges The amount of shearing done on napped fabrics, such as velours and broadcloths, depends entirely on the length of the desired nap On velours sufficient cutting or cropping is done to produce a plushlike effect, whereas on duvetyns and suedes the nap is shortened considerably (see napping) In pile fabrics shearing is done before and after dyeing Broadcloths require the most "cropping" To produce the high luster of a broadcloth, a laid down short nap, the cover has to be shorn off very gradually

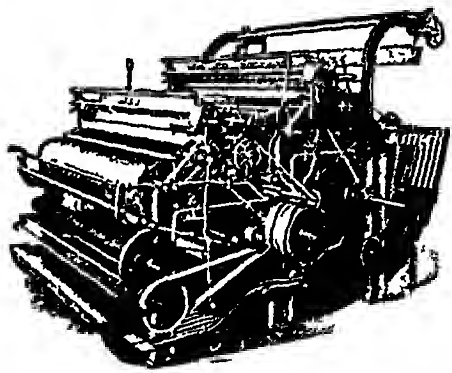


Fig 8 Double cutter woolen shear (*Courtesy Curtis & Marble Machine Co*)

The earliest mechanical shearing machine was constructed as a cross-cutting machine The piece was fastened on pins at the selvages and the cutting device moved over the length of the piece and so length for length was sheared

Modern shearing is a continuous operation The ends of the piece are sewed together and the cloth runs through the machine in an endless band over stretching bars, guide rollers, and brushes at an average speed of 8 to 10 yards per minute The newest, three-plate, automatic shearing machine illustrated in Fig 6, and diagramatically in Fig 7, which has been designed especially as a production machine, can be run at speeds of from 30 to 40 yards per minute or higher if necessary

The cutting of the nap has to be done gradually, meaning that the setting of the cutting device has to be higher in the beginning and gradually lowered to the desired point This method gives a more evenly sheared surface—in trade terms, a round sheared nap If, in the beginning the setting is too low, the cutting device cannot cut the immense amount of fibers at once and the fabric tears

The critical adjustment in shearing lies in the mutual relations of the ledger blade and the cylinder and of these two with the bed Before commencing to shear a piece, the cutting device is adjusted to the bed by inserting a thin paper between the bed and the cloth as it rests on the ridge of the bed By doing this across the width of the

machine and feeling the amount of resistance to the withdrawal of the paper, a judgement is formed as to the pressure between the cloth and the cutting edge. The keenness of the cutting depends on the sharpness of the knives If the machine, when the cylinder is turned by hand, will shear a fine paper with a clean cut, it is concluded that the cutting device is in proper adjustment. With the proper adjustment of the cylinder with the blade and the adjustment of this combined system with the bed, the spirals are able to reach all projecting fibers as they stand up from the cloth when it passes over the ridge of the bed These fibers are then dragged by the revolving spirals against the keen edge of the ledger blade and there cut off (Fig 9)

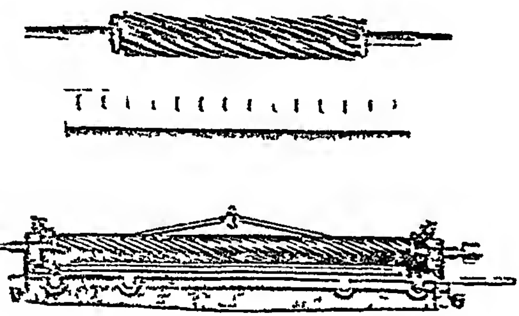
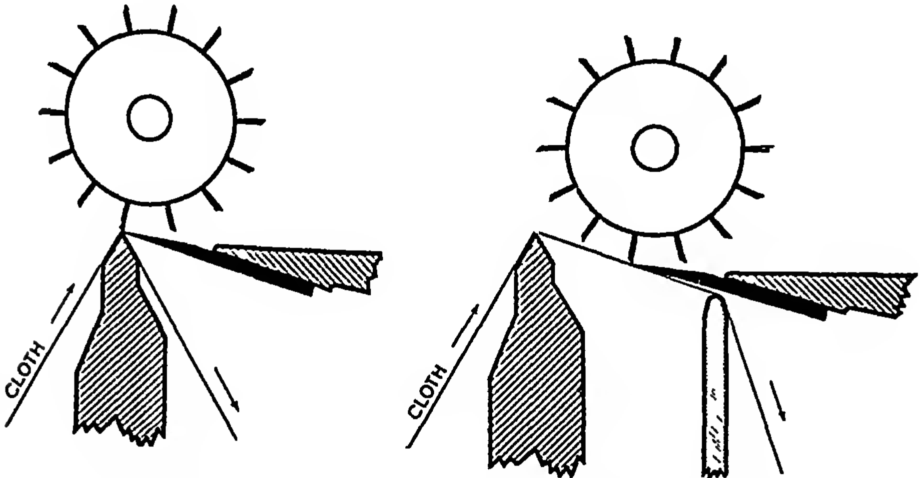


Fig 9 Spiral revolver blade assembly

When the seam of the cloth approaches the cutting point, the cylinder and blade, which is the cutting device, has to be raised by pressing down a lever or foot rest to allow the passage of the seam To this movement the operator of the shearing machine has to give special attention If the seam passes into the cutting device without being disengaged, considerable damage can be done to the cloth, the ledger blade, and the spirals In modern machines the lifting may be done automatically. There are several types of beds over which the fabric travels while cutting takes place · solid or hard rests, hollow or gap rests, spring or India-rubber tube beds In this country the first two are most widely used Smooth-surfaced qualities with nap, such as meltons and velours can always be sheared on a bed with one ridge or hard rest

For the cutting of worsted goods especially clear finished ones and for weaves made of yarns with fancy knots and curls, it is safer to use a hollow bed, which has two ridges about 4 inches apart, known as the "gap rest" (Fig. 10). The cutting device works on the gap between the two ridges and because there is no solid object underneath the cloth, the projecting curls and knots will not be cut off There are three main advantages to the "gap rest." First it reduces considerably the amount of burling necessary, since most of the knots



"Hard rest" shearing "Gap rest" shearing

Fig 10 Two methods of shearing fabrics

do not have to be pulled through to the back and cut before shearing Second, it eliminates all knot holes in finished goods, as it is impossible to produce them with this type of rest On some goods, where the knots are difficult to locate, this is a decided advantage Third, with the new high-speed machine the gap rest allows for continuous production on numerous types of fabrics varying in thickness, without the necessity of resetting the cutting knives

The production with gap-rest shearing is about 20 per cent lower than on the shearing machine equipped with hard rests In the new automatic cloth-shearing machine using hard rests, speeds of up to 50 yards per minute can be obtained, whereas using the gap rest satisfactory shearing is possible only at a speed of about 38 yards per minute A further disadvantage of the gap rest machine is that fact that the plates must have a flat ledger, which is considerably harder to grind

Regardless of what type of machine is used, to secure a clean even cut, it is very important that the cutting device be kept in good condition This necessitates regrinding the spirals and the blades from time to time The sharpness of the blades and the spirals, when properly ground, should last from four to six months, depending on their use

In normal hard rest shearing, it is essential that the back of the cloth be free from weaver's knots and slubs in the yarn and that no flocks get between the bed and the cloth since any of these would lift the material at that point Any lifting of the material results in

an increased cutting action on the upper surface which might even be great enough to cause a hole to be made in the cloth.

Flock removal In the modern shearing room, the shear-flocks are removed from the machine as they are produced In addition to the danger of the flocks adhering to the cloth and causing cut holes and choking running parts, they soak up lubricating oils; shear flocks may soak up as much as 6 per cent of their own weight of lubricating oils To avoid oil stains, a suction system is fitted over the cutting cylinders which, by means of the suction current of a powerful fan, conveys the flocks from the machines to a central separator.

Fancy Shearing

A special development in the art of shearing cloth is fancy cutting, which is often applied to ladies' coats and jackets of the velour type, sometimes called imitation Jacquards This is done by using sector beds and lifting the cutting device at determined intervals According to the design cut on the sector bed, a design will be produced on the surface of the cloth Fabrics of this kind have straight-line designs, either in the warp or the filling direction or running diagonally, simulating stripes and checks or, in more elaborate examples, floral designs may be imitated A more universal system of producing patterns curvilinear or otherwise, is to replace the ordinary bed by an engraved metal roller.

Ratine or chinchilla effects This is a kind of finish applied to ladies' coating and heavy overcoating for men's wear. The finish can be created only on a pile nap The cloth is drawn at a speed of 3 to 4 yards per minute over a stationary, plush-covered table Above this stationary table is placed a swinging table covered with a rubber pad, which rests with its own weight on the surface of the cloth This table is driven by a beveled gear from the side of the machine and its reciprocating motion is controlled by eccentric cams on both sides Five effects can be made by changing the setting of these cams, namely:

1 A bead effect
2 A wave effect in the direction of the warp
3 A wave effect in the direction of the filling.
4. A wave effect diagonal from left to right
5 A wave effect diagonal from right to left

To produce a bead effect the upper table moves at a fast speed in a short circular motion The size of the bead depends on the length of the nap; a short nap will give a small bead and a long nap a larger

bead To produce all other effects the table moves in a reciprocating motion in the opposite direction of the wave In all wave effects the size of the wave is determined by the length of the stroke the table makes in its reciprocating motion

Brushing and Steam Brushing

This is a process which often follows shearing and has for its object the removal of the loose, short-cut fibers which have dropped into the face or nap. It is often combined with steaming, then it is called steam brushing The principal features of such a machine are shown in Fig 11 One of its important features is the laying of

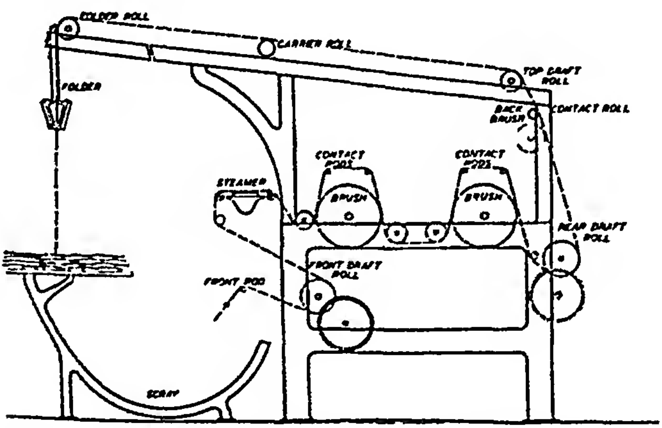


Fig 11 Two-cylinder, double-acting brushing machine
(*Courtesy Curtis & Marble Machine Co*)

the nap in one direction and fixing it in that position with steam. The machine is built on a heavy square frame, normally with two brush cylinders about 13 inches in diameter, double lagged and filled with first quality bristles For cleaning the back of the goods, there is a flock brush with flock pans which catch the flocks and lint removed by the brushes The cloth strikes each brush twice, giving a large brushing capacity The amount of contact on the brushes is governed by hand wheels acting through a simple cam arrangement, which is the strongest and best device used for the purpose; it is perfectly positive at each side and not liable to break or get out of order. The operator can adjust the machine instantly so that both cylinders brush

the goods alike or so that one cylinder brushes the goods more heavily, as may be required

The machines are most commonly arranged with a back folding attachment and a cloth scray for guiding the cloth underneath, as shown in the figure The cloth scray is made with a hinged table at the rear on which the goods are folded after being brushed, and at the same time a new piece may be run into the machine The machines are also built with a top frame by which the goods are carried overhead and dropped into a cloth scray in front, so as to run endlessly or folded neatly on a platform.

A steaming apparatus is set high on the frames so there will be less liability of the steam affecting the brushes The streamer consists of a metal shell with distributing pipe and curved shield inside, so constructed that a uniform supply of steam is obtained the whole length and delivered to the cloth evenly and free from drops of water. The felt cover over the top may be easily renewed when required.

Dry Decating

In the finishing routine, dry decating or dry blowing generally follows shearing Some reference has already been made to the decating process in the sections on crabbing and wet decating in the chapter on wet-finishing operations The essential feature of the process is the application of dry steam to the enclosed dry cloth while in a state of strain The subsequent cooling off produces a permanent setting of the fabric The dry cloth is wound under tension on a perforated decating roller, the general working arrangement being the same as that described in the wet-decating section Under the influence of the hot steam, which provides heat as well as moisture, the wool becomes plastic, causing the tension to be relieved and with it all additional strains present in the form of creases and folds The fibers of the yarns and the yarns themselves that make up the fabric reach an equilibrium resulting in a balanced, unstressed texture The final fixing occurs during the cooling-off period, in which a current of cold air is drawn through the roll Dry decating can be accomplished in either of two ways, by the pressure-blowing or by the open-blowing method, depending upon the permanency of the setting desired

Pressure blowing. The general features of a pressure-blowing machine, also known as a vacuum steamer, are illustrated in Fig 12 This outfit consists of a winding machine, a cooling frame, a boiler, and a vacuum pump The cloth is wound tightly with a fine-faced

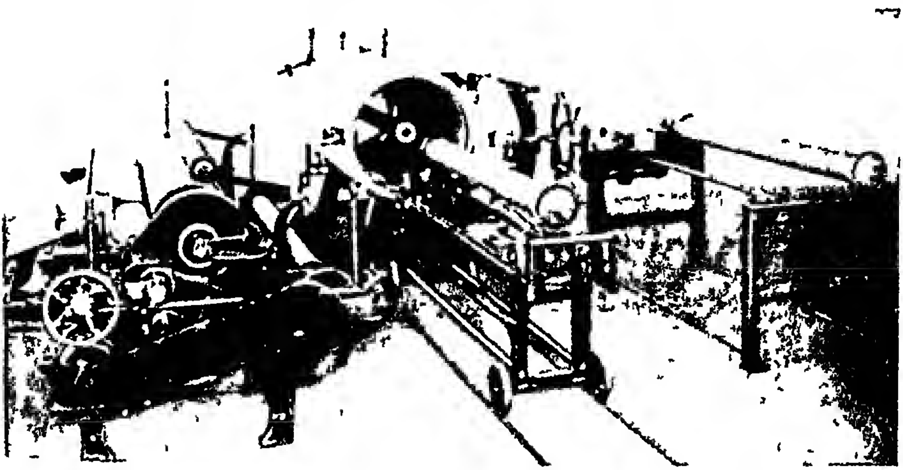


Fig 12 Vacuum steamer with one winder and cooling frame (*Courtesy David Gessner Co*)

cotton leader on a perforated roll Two pieces can be put on one cylinder A heavy leader cloth is wound on top of the finished roll to give the outside end of the cloth sufficient pressure and protection This roll is put into the preheated boiler which is sealed air-tight with a cast-iron cover Before opening the steam valve a vacuum in the boiler is created by means of a vacuum pump Then the steam enters the boiler, first through the inside of the cylinder on which the cloth is wound, and forces its way through the cloth for two or three minutes Then the steaming is reversed The steam enters the boiler and forces its way through the cloth from the outside to the inside for another two or three minutes During this process the cylinder does not revolve The pressure created in the boiler is usually not higher than 20 pounds per square inch The roll is then taken out of the boiler and carried to the cooling frame, where a vacuum pump sucks the steam out of the cloth and also cools it with fresh air This takes from five to ten minutes according to the weight of the cloth The cloth is then unwound By means of this decating process the cloth is "set" in width and length and the handle of the cloth is made firmer and thinner. The pressure of the leader which is wound with the cloth on the roller and the steam pressure in the boiler during the decating process develop plastic setting and leveling of the surface of the cloth. The newest machines are equipped with full automatic controls

Dry decating, as well as wet decating, gives a marked and variable

character, such as brightness of appearance or luster in varying degrees, to the woolen cloth which cannot be produced by any other finishing routine Increased luster, which is caused by a better reflection of light, is the result of the improved smoothness of the surface In some goods it is essential and is developed to a very high degree A high-luster broadcloth is an example Such a luster, when permanent, is unaffected by the weather and is impervious to rain

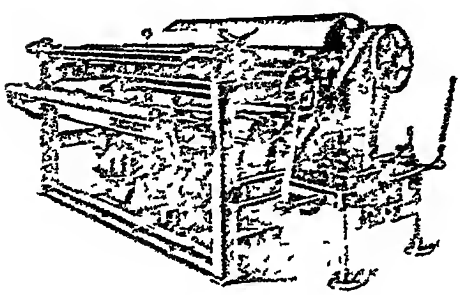


Fig. 13. Mantle-steaming and air-cooling machine.

(Courtesy Curtis & Marble Machine Co.)

Open blowing. The mantle-steaming and air-cooling machine, also called an open-blowing machine (Fig. 13), is often used in place of the closed-blowing machine Its advantage lies in the fact that the danger of tendering the goods is eliminated and the colors are not affected. Open blowing is as a whole a milder treatment and less effective. The process is as follows: The fabric to be processed is wound in a specially woven, smooth-faced, cotton mantle or wrapper upon the steaming cylinder. In winding the goods onto the steaming cylinder, compression may or may not be used as required. Tension is applied to the mantle or wrapper by means of a friction device on each end of the roll on which the mantle is wound. The fabric is subjected to the action of dry steam while enclosed in the mantle on the steaming cylinder. A separator ensures "dry" steam.

The exact amount of steaming on the cylinder varies from one to two minutes, depending on the particular fabric The steam is then shut off and, by opening a quick-acting valve, air is drawn through the cloth in order to cool it The amount of extracting or cooling also depends on the type of finish desired. Ordinarily three to five minutes will be sufficient. After this treatment, the goods are unwound from the cylinder, rolled up, and allowed to stand for a few hours.

Four to six pieces an hour is the average production of a single-cylinder mantle-steaming machine with an 8-inch or a 12-inch cylinder, when one piece or cut of goods is treated at a time. This capacity is increased materially when a 24-inch cylinder is used and two pieces of goods are treated at the same time.

A convenient arrangement for rapid and efficient blowing is to put two double-roller machines side by side on the same exhaust pump. In such a system the operator is able to do the winding on one machine while the other is cooling off.

The highest and most permanent luster in woolen fabrics is obtained by repeated wet and dry decating. In many instances, luster is not desired but, since decating is necessary to set the cloth, the excessive lustering must be removed by open steaming. All decating processes, if not carefuly applied, can produce serious defects and are therefore avoided by many cloth finishers. Such defects are harshness of feel, paper handle, water marks, and change of shade. The harsh and papery feel is a result of loss of moisture when the pieces were subjected to high temperatures. Normally, the pieces are able to regain the lost moisture on standing, thus becoming reconditioned, but in case the harshness does not disappear the pieces must pass through another wet process.

Damping or Dewing

Woolen and worsted products are often subjected to a damping or dewing process before being hot pressed. Saxonys and some tweeds, which can be cold pressed, are the only exceptions. Most woolen and worsted products are subjected to hot pressing. In hot pressing, the wool in order to obtain full benefit of the operation must pass into the plastic state. Not only heat but also moisture is necessary to bring this about, therefore, the fabric must be properly conditioned.

The cloths as they come from the tenter frame and from the blowing processes generally are overdryed, often containing less than 5 per cent moisture. Such pieces will not take a press finish properly and will have a thin, papery handle. It is, therefore, good practice before pressing, to bring the fabric into the required condition by dewing or by storing it sufficiently long in a damp atmosphere. In any contact of woolen cloth with heat, the hot surface has the effect of liberating moisture because (as explained in the chapter on the physical properties of wool) the regain of the wool substance at higher temperatures is diminished. This aspect of cloth pressing is well understood by the housewife, who sprinkles cottons before ironing and uses a damp cloth on woolen fabrics while pressing, and by the professional tailor, who commonly applies a damp cloth or presses with a steam iron.

There are two types of machines employed in the dewing operation,

namely, the brush machine and the nozzle machine Their main object is to distribute evenly a fine spray of water over the cloth The amount of water added to a fabric can be regulated according to the type of cloth

To hold the water the brush machine has a trough in which a grooved, wooden roller revolves Over this roller, revolving at a high speed, is a circular brush which takes the water from the wooden roller and distributes it in the form of a fine dew or mist on the cloth as it passes over it

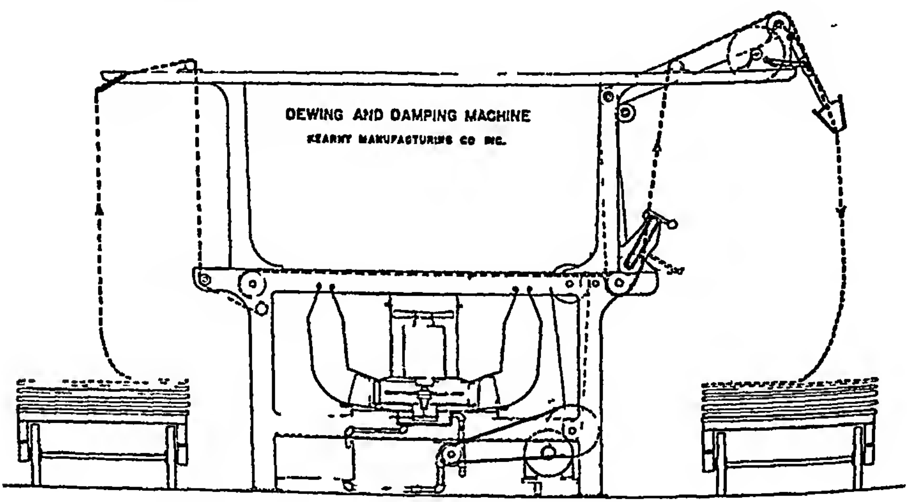


Fig 14 Nozzle-type dewing and damping machine
(*Courtesy Kearny Manufacturing Co, Inc*)

The principal features of a nozzle machine are illustrated in Fig 14 The machine employs two nozzles and a miniature propeller in which are cut a series of spiral grooves The streams of water passing through the grooves of the high-revolving propeller are emitted from the two nozzles in the form of a very fine, mistlike dew, which is applied to the fabric during its passage over the conditioning ducts The water is drawn from a tank through a fine sieve, and all water not taken up by the material flows back through a return pipe into this tank, to be used over again The machine is equipped with three speeds, varying from 7 to 20 yards per minute, and three adjustments—fine, medium, and full spray—can be made, governing the amount of water sprayed onto the goods The water pickup may vary from 1 to 8 per cent

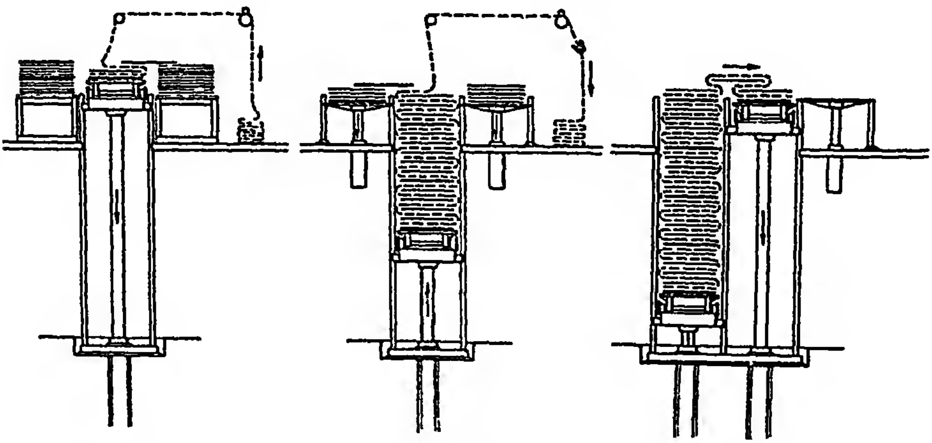
Pressing

As a rule, the process of pressing is the last of the finishing treatments and therefore demands the utmost attention Its object is the last leveling and flattening of the texture and, at the same time, pressing brings out the handle, luster, and appearance desired in the finished fabric The basic factors controlling pressing are heat, moisture, pressure, and time Since all four of these factors can be varied, there are infinite combinations which can be used The principle of the various kinds of machines used for pressing woolen and worsted goods differs in the way use is made of these four physical factors

The old fixed hydraulic paper presses used a moderate temperature over a longer period of time The new intermittent and rotary presses employ higher temperatures over a very short time, thus giving increased output There is no question that in point of fine finish, soft handle, and appearance the old method is superior

There are two distinct systems of pressing in one, pressure is applied vertically and, in the other, longitudinally In both systems the machines used employ the hydraulic principle to secure the necessary pressure There are at present three types of pressing machines in use the vertical paper press, the intermittent vertical paper press, and the rotary press In the vertical paper press the cloth is folded between heated press papers, piled into a stationary hydraulic press, and compressed for several hours In the intermittent vertical paper press the cloth is fed intermittently between papers held in heated gaps, and compressed for a few seconds A new portion of cloth, equal to the width of the plates, is then fed forward and the process repeated In the rotary press the cloth travels between two heated metallic surfaces, forced together either by a hydraulic ram or by mechanical means, thus giving continuous action

Vertical paper press This installation, shown in Fig 15, is usually erected on two levels The papering-in, the turning, and the papering-out processes are carried out on the upper floor, whereas the heating up and the actual hydraulic pressing is carried out on the lower floor In papering in (Fig 15A), the cloth is drawn forward over suitable guide rollers onto the table of the middle lift, a stack of papers being in position on each of the end lifts As the cloth is fed to the middle table, each of two operators standing on opposite sides inserts press paper made of glazed cardboard between each layer of cloth Each twelfth cardboard has a metal lining with exposed metal tabs which serve as electrical contacts for heating As the piles alter in height, the levels can be adjusted by operating levers controlling the three



A Papering-in B Papering-out C Turning

Fig 15 Automatic cloth-handling in a vertical paper press (*Krantz*)

hydraulic lifting presses As the middle one is slowly lowered, the outer two, which carry press papers, are gradually raised When about twenty pieces are thus papered, the middle lift is lowered to the floor below A movable platform is then brought opposite the lift and the full load run onto it Small trucks are used to transfer the load of cloth with the paper from the papering lift to the hydraulic press It is then pushed in front of the press and run into position

This press consists of a lower and an upper heavy metal plate, fastened together by four steel pillars A hydraulic pressure arrangement presses the lower plate carrying the load of cloth folded between the press papers and metal plates against the top Up to thirty-five pieces can be pressed in a machine at one time The metal tabs mentioned above are then connected to the electric current which distributes the heat evenly through all layers of the cloth A hydraulic pressure of 450 to 500 pounds per square inch is sufficient to produce the desired effect The cloth remains under this pressure from three to four hours It is then taken out and transported back to the lift arrangement for turning or refolding (Fig 15C) In the turning process the cloth is refolded between press paper in a manner similar to that of "papering in" but the edges of the cloth which overlapped the press papers in the first pressing will be placed in the middle as the pressing process is repeated The papering out which follows the second pressing is illustrated in Fig 15B In papering out,

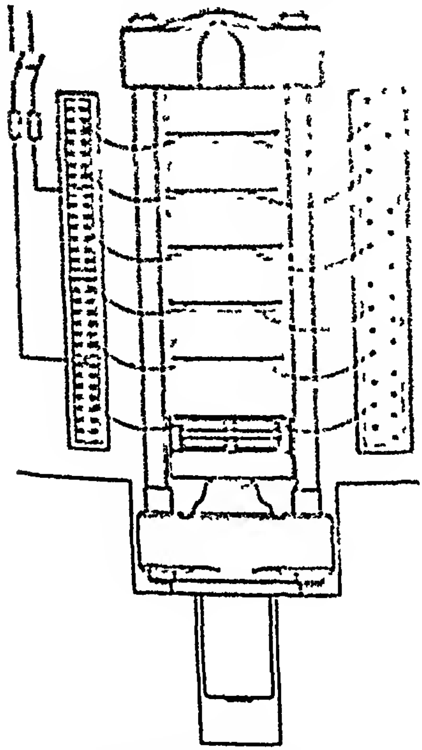


Fig 16 Fixed vertical paper press, electrically heated

the batch is taken to the middle [illegible] the cloth is drawn out by the roller mechanism, and the papers withdrawn and delivered to the [illegible] lifts ready for the next batch of pieces

It is thus apparent that the operations are largely automatic, the actual work of papering being unskilled Only one competent workman, usually the foreman finisher, is required to decide the time, heating, and pressure necessary to obtain the requisite finish for particular fabrics

Intermittent vertical paper press This machine, also known as the automatic, flat-plate press, is very popular with British finishers It was designed to carry out automatically the function of the stationary paper press The principle features of this machine are seen in Fig 17 This machine consists of a top plate *A* and a lower plate *B*, which is connected to the double hydraulic ram *C* Between upper and lower plates is an intermediate plate *D*, which is capable of sliding up and down between guides All of the plates are hollow and connected by flexible pipes to a steam supply Owing to the short contacting time, the temperature necessary is much higher than that used with the nonautomatic vertical press The openings between upper and middle plates, and middle and lower plates are taken up by the cloth and the press paper The pressure is created by the two hydraulic rams The smaller ram lifts the lower plate *B* and hence, a little later, the middle plate *D*, subsequently closing the two gaps containing the papers and the lengths of cloth At this point, the larger ram comes into action, applying the requisite full hydraulic pressure

As its name implies, the machine is automatic in operation, the cloth being conveyed through the gaps and the pressure applied without any attention from the operator beyond the stitching of the end

of one piece of cloth to the next Two men can easily manage the largest-size machine

The machine presses intermittently, the application of pressure and the conveying of the cloth being controlled accurately by a simple but ingenious system of cams and levers Briefly, the cycle of operations is this the rollers, and therefore the cloth, being at rest, hydraulic pressure is applied to the ram, the plates rise and the cloth is pressed After a given time, the pressure is released, the plates fall apart again, the rollers revolve, and the cloth is drawn forward a distance equal to the width of the plates The rollers stop, pressure is applied to the ram, and the cloth previously unpressed now receives a pressing This cycle is repeated four times per minute

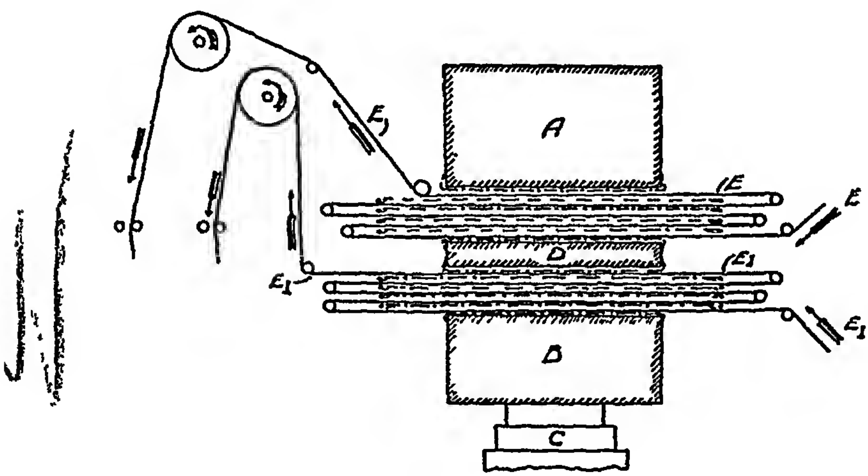
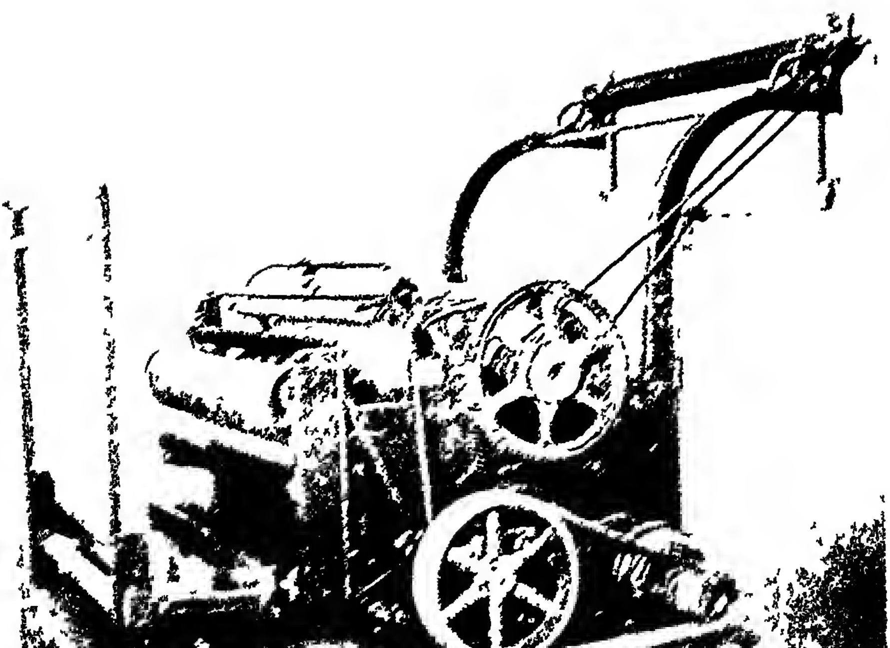


Fig 17 Patented automatic hot-plate pressing machine
(*Courtesy F Hattersley Pickard & Co*)

The machine just described is known as the double machine and will press two full-width pieces or four narrow-width pieces at one time, at rates of from 250 to 700 yards per hour The newest machine is built to handle three pieces, full width, at the same rate of speed The newest development in this field is the introduction of a combined automatic hot and cold press, in which alternate hot and cold plates are used A hot-press finish can be applied to the cloth, followed immediately, without stopping the machine, by a cold-press finish This has the effect of cold flattening under pressure, thereby setting the



lined with a smooth-surfaced metal jacket. The face of the cloth, when passing through the pressing parts, is against the latter The desired press effect can be regulated with a variation of pressure. This process is continuous and the speed of the cloth is from 4 to 15 yards per minute For light pressing or smoothing, an apron press is used An endless felt travels with the cloth between the bed and the cylinder

There is one disadvantage in pressing cloth on a rotary press as compared with pressing on a vertical hydraulic press In the rotary press the cloth receives a certain stretch, whereas in the vertical press the cloth is pressed in a stationary state, with no pull or friction on the cloth Therefore, better qualities of cloth should be pressed on the hydraulic press

Final Steaming and Sponging

Steaming Steaming is a simple operation, but a very important one in the finishing routine The steaming operation, when applied after drying, shrinks and partly conditions the cloth It also loosens up the fibers for the cutting process that follows When applied after final decating, steaming takes off the surplus glaze and, no matter when applied, has a tendency to shrink the cloth in width and length

The machines used for this operation are constructed in several ways The main part is the steam box, about 2 feet wide, with a perforated copper cover, which is again covered with burlap and a heavy leader cloth The cloth runs over guide rollers and tension bars and then over the steam box A pull roller pulls the cloth through the machine and a folding device folds the cloth evenly on a truck On some types of steaming machines a rotary brush is mounted behind the steam box, where the nap on fabrics like broadcloth is brushed and laid down after it passes over the steam box (See the previous section on brushing)

Another type of steaming machine is constructed especially for shrinking or sponging purposes. The machine has a 72-inch working width and consists of three integral parts the steaming unit, the heating or shrinking table, and the cooling apparatus The cloth enters at the steaming unit, which consists of two copper steam boxes with ball-bearing idler rollers ahead and between the steam boxes From there the fabric is delivered onto the inclined heating table over the top of which it slides, almost no tension being exerted on the fabric while it is undergoing the actual shrinkage The heating table, which measures 60 inches by 72 inches, has a highly polished, heavy-

gauge, copper plate, underneath which a series of steam-heating coils are located

From this shrinking table the cloth falls into a scray, where a few yards of the fabric are accumulated From the scray the fabric is picked up again and brought over the cooling apparatus, which is comparable to a wide vacuum trough This trough is connected to a powerful suction blower, and the cloth is thoroughly cooled and set before it is rolled up at the extreme end of this unit, or before it is folded onto a carriage folder operating on rails underneath The driving mechanism is mounted beneath the steaming unit and has a variable-speed apparatus Its production is 8 to 23 yards per minute

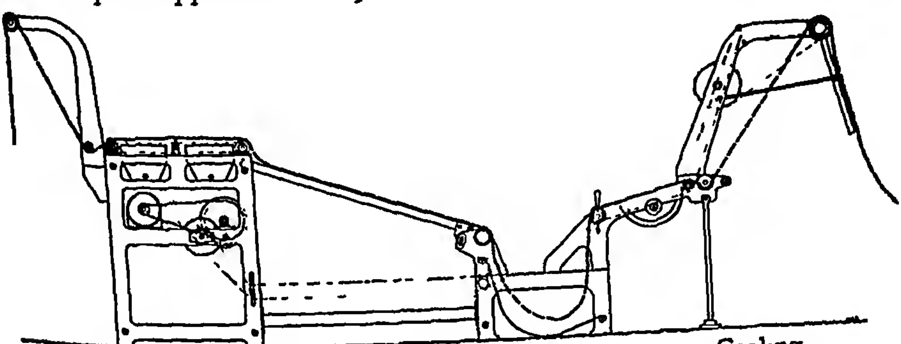


Fig 19 Full-shrink finishing machine (*Courtesy Mawaco Machine Co*)

Sponging The final decating operation, as the name implies, gives a final touch, handle, and shrinkage to the cloth Different types of machines are employed (Figs 19 and 20)

The important factors in the different types of final decating machinery are the diameter of the decating cylinder, the suction pump arrangement, and the means provided for decating the cloth with or without a leader Older machines have a small cylinder from 8 to 10 inches in diameter, whereas on the newer ones the diameter of the cylinder may be up to 40 inches It is easy to understand that when a piece of cloth is wound on a small-size decating roller together with a thin cotton leader, there is not much chance for the cloth to shrink, especially in length The leader cloth prevents the piece from shrinking On the other hand, if a cloth is wound on a decating cylinder with a 40-inch diameter (also with a leader cloth) there will be fewer layers of cloth on the roll due to the size of the cylinder and, therefore, the cloth has a greater chance to shrink, especially if a heavy, soft napped cotton leader is used The handle and the touch vary

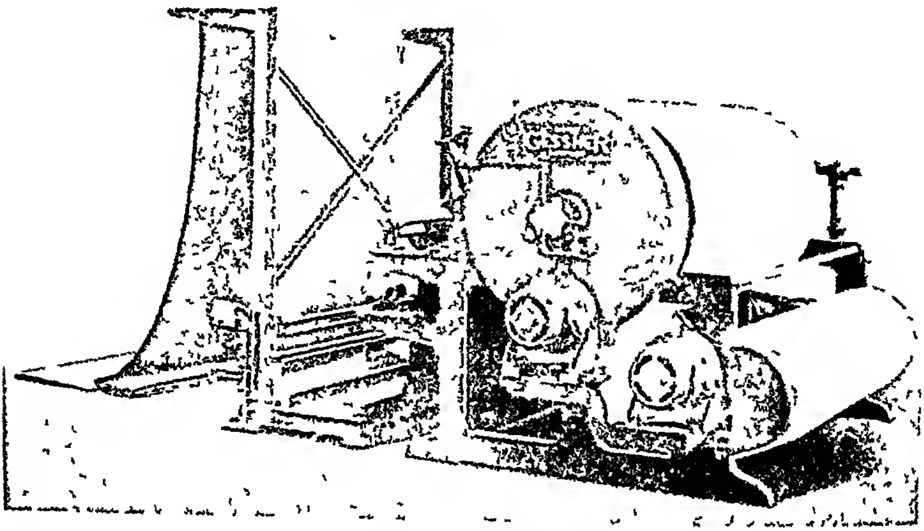


Fig 20 Open steamer with guiders and platform
(*Courtesy David Gessner Co*)

considerably according to the type of leader In some cases no leader is used at all

On either machine the cloth is wound on a perforated cylinder, which for the protection of the cloth is covered with burlap and with a heavy leader cloth The steam enters this cylinder and forces its way through the cloth Steaming time depends on the result desired, usually from one to five minutes Then a vacuum pump sucks the steam out of the cloth A variation in the final finish is also obtainable by this operation When the steam is entirely removed from the cloth it will take on a certain amount of luster If the steam is only partly removed a duller effect will result and by taking the cloth out of the machine an additional shrinkage will take place due to the greater moisture and heat content of the cloth The take-out roller is also perforated and connected by an air line to the suction pump, where the cloth is cooled by passing over this roller

One final decating machine is so constructed that the cloth is carried by means of endless belts through two decating tables that have an adjustable pressure arrangement From here it is carried in a loose state over guide rollers where the shrinking of the cloth in length and width can take place freely Then the cloth is passed over a cooling table, which is connected with an air suction pump The air

from the room atmosphere is sucked through the cloth and extracts the remaining steam and heat from the cloth. A greater shrinking effect can be obtained in this arrangement because the cloth is not prevented from shrinking by being rolled with a leader on a roller. Also the desired finishing touch on the cloth is better controlled by the adjustment of the pressure arrangement on the decating tables. In this operation the steam pressure should not exceed 30 pounds. The more moisture the steam contains the better the final result will be.

Examining

This operation is performed several times during the finishing routines to detect imperfections, stains, and damages which may have occurred during the finishing operations. As a rule the cloth passes through two inspections in wet finishing and three after dyeing. The number of inspections necessary depends largely on the equipment of the plant and the skill of the workers on the machines.

In wet finishing one examination is practical after scouring, fulling, and carbonizing and one at the last stage before dyeing. After dyeing and drying, the cloth has to be inspected for color and for any wrinkles which may have occurred. An inspection of the cloth is necessary after shearing to detect small knot holes, oil stains, and cuts.

The most important of all examinations is the one at the end of the finishing routine when the cloth is thoroughly inspected for all

introduced to the United States in 1902 by the Kaumagraph Company

The dry transfer consists of a strip of tissue paper on which a design, trade-mark, or description has been printed in fusible ink from a metal engraving When laid face downward on a piece of fabric and pressed with a heated iron, the fusible ink adheres securely to the fabric When the paper is lifted the design or printing has been transferred to the fabric

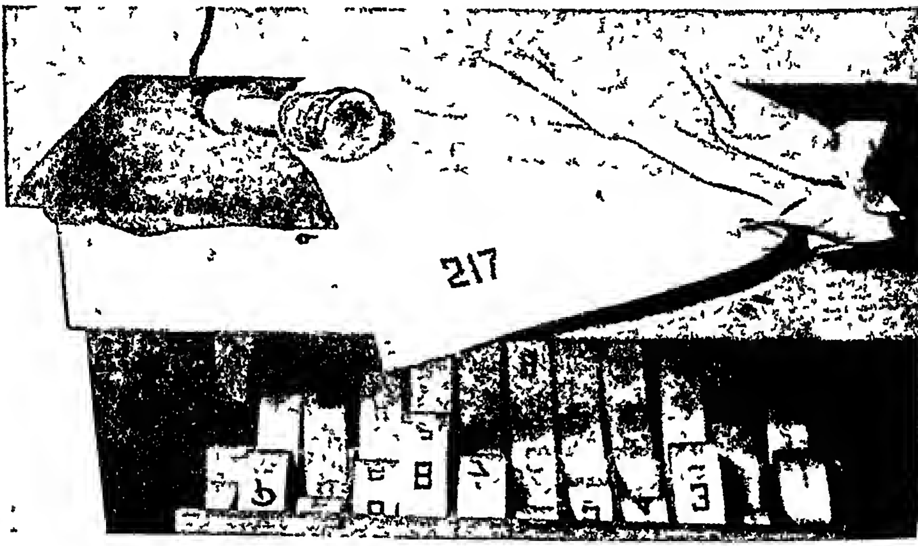


Fig 21 Fulling numerals reproduced by means of a heated iron
(*Courtesy Warren Woolen Co*)

Stamping was originally done as a protective function, known as "truth markings," applied to the inside and the outside end of pieces The ease of marking with dry transfers has caused stamping to become much broader and of more informative significance In many mills stamping is the standard means of numbering, truth marking, and of marking for shrinkage control and other identification purposes essential to the processing of woolen goods The more informative significance was brought about by the use of stamping to apply the trade-mark of the manufacturer on the back of the cloth or along the selvages On woolens stamping became a guarantee to the cutter against impurities in content, shrinkage, and incorrect shade, a proof to the wholesaler of authenticity of manufacture, and a guide to the consumer for quality purchasing

Individual digits to make up any required number can be reproduced by means of a hot iron applied manually or automatically to a dry transfer specially developed for this numbering process. The Transferotor (Fig 22) is a device which can be adapted to many cloth-handling machines or which can be built as a unit It is used for applying transfers at regular intervals on a piece of material The transfer in roll form is situated in the Transferotor. At predetermined intervals a self-contained electric iron applies the transfer to the web of cloth moving at speeds of 80 to 100 yards per minute Frequently this is combined with measuring, folding, winding, and other cloth-handling operations The Transferotor offers the advantage of close printing on the tissue with reproduction on the cloth at wide intervals, usually 1, 2 or 2½ yards.

Fig 22 Marking during winding process Transferotor with dry transfer rolls (*Courtesy R W Hull Co*)

Transfers can be applied to the back or selvage of cloth by leading the paper from the transfer roll into the calender stack or pressing rollers This allows the natural heat of the operation to apply the transfer to the cloth This method is more expensive than that of the Transferotor since transfer printing is spaced on the paper to coincide with the required spacing on the fabric, usually 18 or 36 inches

Measuring and weighing are necessary to ascertain the exact length of the cloth and the weight in ounces per yard Here, then, is the control for the finishing operations for shrinkage and weight as well as the control of layout, count of yarn, and number of picks and ends. If all the manufacturing operations are up to standard, the correct weight and shrinkage of the finished cloth will indicate this In double folding the cloth is rolled evenly on a cardboard in half the width and in rolling the cloth is rolled in full width on a tube

In this final condition the cloth is delivered to the merchandise department for shipment to the trade

CONDITIONING BEFORE CUTTING-UP

Specially prepared with the co-operation of Leonard Garfunkel

After woolen and worsted goods (either all wool or wool with mixtures of other fibers) leave the loom, they pass through the series of mill-finishing operations described in this chapter which render them salable The final preparatory phase through which these cloths should go before they can be used on the cutting table is an examination and a thorough preshrinking The examination of the goods consists of the passage of all pieces in the lot or order over a perch. Behind the perch stands a skilled inspector whose responsibility it is to catch every imperfection and to indicate various damages by inserting and tying a string in the selvage on either side

Examination of the Goods

The examination defects fall into two principal classes apparent or visible defects and latent defects In the first class come various mispicks, bars, roweyness, uneven filling, warp runners, holes, stains, shadiness of color and tenderness The last two defects often can render the goods unmerchantable In the class of latent defects are included streaks, which appear after pressing and in the case of napped goods, pilling after less than reasonable wear, and undue fading of colors Washer streaks and lay wrinkles do not always appear in the goods when they are perched or examined and often appear afterward as a latent defect

Passable piece goods are now subjected to different preshrinking operations which are carried out by modern and efficient machinery Two principal methods of shrinking woolens and worsteds, contain-

ing all wool and also those containing vegetable fibers and manipulated yarns, are used shrinking by treatment with steam and shrinking by treatment with cold water The latter is known as London shrinking

Steam Shrinking

Steam shrinking is carried out by means of one of three machines, the choice of which depends on the character of the goods and its fiber contents

1 *The open steaming and cooling machine* is used chiefly for coatings, overcoatings, and similar heavy goods, and for napped and pile fabrics Minimum tension on the cloth and a proper cooling with suitable folding down attachments are essential in obtaining satisfactory results with this method

2 *The cylinder steaming machine* is used chiefly for men's suitings, tightly woven tweeds, and similar fabrics which require stationary and double steaming These cloths are properly cooled by being left for a sufficient length of time on wooden poles or rods on a cooling frame This machine also is used for fabrics containing vegetable fibers, which have a greater resistance to steam than wool and therefore require a longer and more severe treatment

3 *The decating machine* contains a perforated cylinder (or a pair of cylinders) around which is wound a cotton leader of soft or hard character depending upon the finish desired on the goods Lightweight dress-goods are "set" by this process with a minimum shrinkage and a retention of their original appearance Coatings, requiring a high face-finish, particularly broadcloths, are also finished by this process

Semidecating is sometimes used on cloth which has been shrunk already, and which under the steaming process might regain some of its lost dimensions This regain would cause the finished garment to shrink again under dry cleaning In semidecating the cloth is put into the hot leaders after the steam has been shut off. It is not subjected to live steam

London Shrinking

The second main process, also known as cold-water shrinking, is used primarily in the United States for fine men's-wear worsteds It calls for three principal operations, namely, dampening, drying, and refinishing

1 *Dampening*. Dampening consists of wetting the goods in the following manner A raised platform from 3 to 6 yards in length is

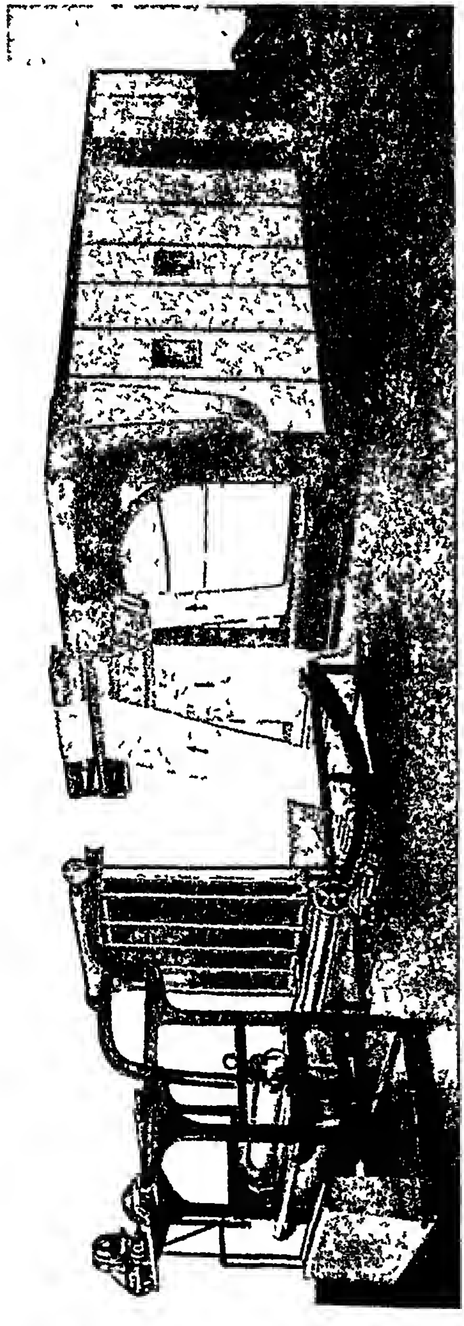


Fig 23 Continuous London-shrinking machine (Courtesy David Gessner Co)

used Cotton or woolen blankets are thoroughly wetted and constitute the medium for dampening A wet blanket is first laid on the platform and the first layer of the cloth is placed on top spread in full Wet blankets and cloth are alternately spread out on the platform The number of layers of cloth as compared to the number of blankets used between them varies according to the weight of the fabric and is governed by practical experience When the requisite number of pieces is laid in between the blankets, sufficient weight is put on top of the entire pile so as to compress the various layers and so that the wet blankets come in contact thoroughly and evenly with the cloth being processed The cloth is allowed to remain in this condition for about twelve hours, and then the dampened cloth is removed from the platform.

In recent years an alternate method has been substituted for this blanket treatment The goods are subjected to direct spray, or, in the case of heavy materials such as overcoating, they are passed through a tank of water In the latter case they are put through squeeze rollers before being hung to dry

2 *Drying* Drying is accomplished by hanging the dampened goods on sticks and in folds until they are thoroughly dried by natural room air, or through the medium of forced air currents in regular drying machines or automatic festoons equipped with steam coils The closed- or forced-drying apparatus which generates heated air is the method more often used, because the cloth dries more quickly and consequently speeds up production However, the open-drying apparatus with air circulators at the top and bottom for the purpose of moving the natural air gives to the cloth a greater mellowness than the closed- or forced-drying apparatus

3 *Refinishing* When the cloth has been completely dried it is subjected commonly to hydraulic pressing For this purpose the cloth is folded on a small feeding cart and placed alternately, in bookfold fashion, between especially made press boards At specific intervals, in addition to top and bottom layers, are placed metal plates, preheated in a convenient oven The entire setup of the cloth, boards, and plates is now trucked into the hydraulic press and a pressure of 3,000 pounds is placed on it The cloth is allowed to remain in this compressed condition for about ten to twelve hours It is then ready to be wound on wooden spindles or cores and brought back to the examiner for re-examination and detection of any possible latent defects that might have developed during the process Finally, the cloth is rolled and remeasured, after which it is ready for the cutting table

Degree of Fabric Shrinkage

Properly constructed fabrics of the types usually treated by the steam-shrinking method should average a shrinkage of 1½ to 4 per cent per square yard. It is not unusual, however, to find such fabrics shrinking as much as 5 inches in width alone Overtensioning in the machine will tend to stretch the goods and cause extra shrinkage in the width

Properly constructed fabrics when submitted to the London-shrinking method should average a shrinkage of about 5 per cent per square yard. If fabrics shrunk by this method are also subjected to steaming there will be an undue opening up of the fibers, this opening up causes a regain in yardage resulting in further shrinkage in the goods under the pressing iron This applies to gabardines in particular

The mechanical "holding out" of fabrics during this conditioning either by speeding up the machine or by applying half the normal steam pressure, will result in a fabric that will shrink further in

pressing or wear in wet weather This is a practice that should not be tolerated

Excessive shrinkage of wool fabrics may be traced to one or more of the following causes

1 Short fibers in the raw stock which cause a felting when the fabric is subjected to steam treatment

2 Loose and open weave effects insufficiently bound or tied in

3 Overfulling (requiring consequent stretching to give the fabric deliverable and desired width)

4 Reaction of certain dyestuffs and chemicals on the fibers

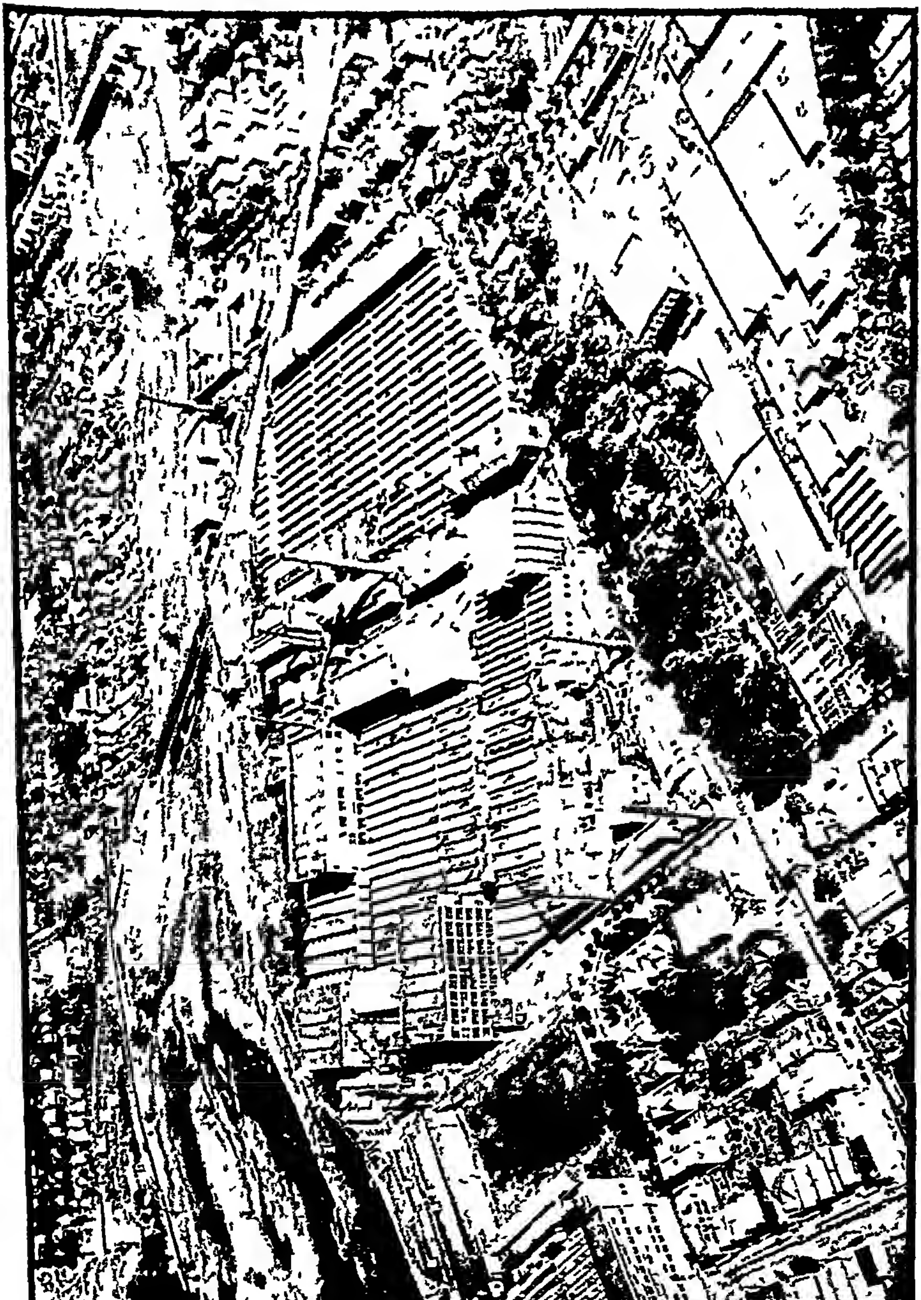
The steam treatment of 100 per cent wool fabrics should generally ensure consumer satisfaction If, however, the fabrics contain cotton, rayon staple fiber, or other fibers carded, blended or woven with the wool, they must be treated in a special manner that is predetermined by careful analysis This is because of the varying resistance to shrinkage of the radically different fibers used in the construction of many present-day fabrics If the manipulated fabrics do not react properly to steaming, the fabrics must be treated by the London-shrinking method to ensure satisfactory results

Unshrunk or improperly preshrunk wool fabrics are unsatisfactory to the cutter-up and the consumer because

1 The fabric will not react properly under the hot iron when the garments are manufactured

2 The garment will shrink when the consumer sends it to the dry cleaner

3 The garment will shrink when subjected to rain, excessive humidity or moisture in the air, and body perspiration



Botany Worsted Mills, Passaic, N J *Photo Fairchilds Aerial Surveys, Inc*

Chapter 21

THE MANUFACTURE OF CARPETS AND RUGS

WOOLS used in the manufacture of carpets and rugs are imported from Asia Minor, China, India, South America, and other countries where the native sheep possess a coarse, wiry, tough fleece American wools are too fine and soft to be used in carpets, but are employed primarily in clothing and knitting yarns If carpets were made from domestic wools they would mat down and wear very rapidly Carpet wools range from 1 to 13 inches in length and from 15 to 70 microns in diameter. In addition, the carpet wools show a tremendous range of luster, strength, crimp and resilience characteristics

Table 1 lists most of the important varieties of carpet wools, the country of production, and character and usual grade of the wool Many of the wools included in this table come on the market as pulled, skin, or tanner's wool

TABLE 1

MAIN CARPET WOOLS

Grades	*Length (inches)*	*Yield (per cent)*	*Descriptions*
Afghanistan			
Afghanistan	1 to 7	65 to 75	Long, white, coarse, kempy
Arabia			
Arabian	1 to 8	65 to 75	Long, lofty, soft, medium
Argentina			
B A 5/6's Fleece	1 to 13	68 to 75	Long, silky, coarse 12 mo growth
B A 5/6's Nov 2d Clip	1 to 8	60 to 70	Coarse, silky 6 to 8 mo growth
B A 5/6's Mar 2d Clip	1 to 5	67 to 72	Coarse, silky 4 to 6 mo growth
Cordova Fleece	1 to 13	52 to 60	Long, coarse, kempy 12 mo fleece
Cordova 2d Clip	1 to 6	48 to 55	Coarse, kempy 6 to 9 mo growth
Criolla	1 to 8	48 to 55	Long, medium, coarse
British Isles			
Haslock	1 to 14	75 to 85	Coarse blackface type Pulled wool
Scotch Blackface	1 to 15	65 to 75	28 to 32 Very coarse with kemp and gray
English Wethers	1 to 13	65 to 75	36 to 40 Crossbred Lustrous, long
Radnor	1 to 10	65 to 75	36 to 40 Welsh mountain Lustrous, long
Scotch Cross	1 to 13	65 to 75	36 to 40 Crossbred Lustrous, long
Irish Kerry	1 to 12	60 to 75	28 to 32 Medium length Coarse, kempy
Welsh Mountain	1 to 10	60 to 75	28 to 32 Welsh mountain Medium length Soft but springy staple, kempy

MAIN CARPET WOOLS—(*Continued*)

Grades	*Length (inches)*	*Yield (per cent)*	*Descriptions*
Cape South Africa			
Cabretta	1 to 4	75 to 85	Hybrid fiber part goat Low-grade kempy.
Kempy Cape	1 to 4	75 to 85	Practically all kemps Short
China			
China Northern Fleece	1 to 6	40 to 45	Medium fine, kempy
China Open Ball	1 to 4	60 to 65	Very fine, but kempy. Combed or pulled from sheep
China Hinning	1 to 8	55 to 60	Long combing length Medium coarse, kempy.
China Chinchow	1 to 5	45 to 50	Average length Coarse, kempy carpet type
China Koolung	1 to 5	45 to 50	Average length Coarse, kempy carpet type
China Hailar-Manchurian	1 to 8	45 to 50	Average length Very kempy, coarse wool
China Urga-Mongolian	1 to 8	50 to 55	Average length Quite kempy, coarse wool
China Uliasutai	1 to 7	50 to 55	Average length Medium amount kempy
Shantung	1 to 6	45 to 50	Southern wools not as kempy as northern
Szechwan	1 to 8	55 to 60	As above More yellow, long
Woosung	1 to 4	45 to 50	As above Very yellow, soft, fine, few kemps
Shanghai Skin	1 to 4	55 to 60	As above Shorter, lime-pulled
China Lambs	1 to 4	45 to 50	Very fine
Cyprus			
Cyprus	1 to 14	50 to 55	Long, coarse carpet
Egypt			
Egyptian	1 to 8	65 to 85	Medium length, coarse
France			
Mazamet	1 to 4	75 to 90	Blend of various pulled, medium coarse wools
India			
Bhatinda	1 to 7	65 to 85	Medium length, resilient, lofty
Bewar	1 to 4	70 to 85	As above
Bibruck	1 to 4	65 to 85	As above
Fasilka	1 to 9	70 to 85	As above
Harnai	1 to 5	75 to 85	As above
Marwar	1 to 4	65 to 85	Very kempy, straight
Peshawar	1 to 6	65 to 85	Medium length, lofty, resilient, some kemp
Vicanere	1 to 7	70 to 85	Medium length, lofty wool
Iraq			
Awassi	1 to 10	65 to 85	Medium fine, lofty Of the better carpet type
Karadi	1 to 14	70 to 90	Coarse, long combing
Morocco			
Morocco	1 to 10	45 to 65	Medium length, medium fine, very lofty
New Zealand			
New Zealand Fleece	1 to 12	65 to 75	36s to 40s Medium, lustrous
New Zealand Crutchings	1 to 8	70 to 70	36s to 40s Short wool
Iran			
Persian	1 to 8	65 to 85	Good carpet types Good length, lofty, resilient
Bagdad	1 to 8	65 to 85	Good carpet types Good length, lofty, resilient
Persian Gulf	1 to 8	65 to 85	Good carpet types Good length, lofty, resilient
Portugal			
Churra	1 to 14	35 to 80	Very long, coarse, yellow with red hair
Oporto	1 to 14	35 to 80	Very long, coarse, yellow with red hair
Russia			
Donskoi	—	65 to 85	Medium length and fineness, white wool
Georgian Section Nouka	—	65 to 85	As above
Spain			
Spanish Pyrenees Fine	1 to 10	40 to 55	Medium length, medium fineness, good resilient
Spanish Pyrenees Medium	1 to 12	45 to 60	Long, slightly coarse, strong wool
Spanish Pyrenees Coarse	1 to 14	50 to 65	Very long very coarse

MAIN CARPET WOOLS—(*Continued*)

Grades	*Length (inches)*	*Yield (per cent)*	*Descriptions*
Syria			
Aleppo	1 to 14	55 to 90	Long combing length, very resilient
Damascus	1 to 12	55 to 90	Long combing length, very resilient
Syrian	1 to 12	55 to 90	Long combing length, very resilient
Turkey			
Anatolian	1 to 12	40 to 60	Long, medium fine wool
Smyrna	1 to 12	40 to 60	Long, medium fine wool
Kassapbatchi	—	40 to 60	Long, medium fine skin wool
Tibet			
Tibet	1 to 10	55 to 70	Soft
Uruguay			
Montevideo	—	60 to 75	36s to 40s Lustrous, long, strong
Central Europe			
Zackel	1 to 14	50 to 90	Long, very hairy, and coarse wool

Source Alexander Smith & Sons Carpet Company.

Analysis of Carpet Wools

It has already been pointed out that carpet wools are of the mixed wool type and consist of a mixture of true wool, hair, including heterotypical fibers, and kemp.

Chen, in trying to find the ideal carpet wool type, made a study of five samples of Chinese wools and compared them with Vicanere and Aleppo wools, which were considered by mill men to be the ideal types of carpet wool A sample of Romney Marsh wool was also included in the study, as this type of improved wool is similar to the carpet types and is often used for this purpose.

Description of samples 1 True Sining wool is a type of Tibetan wool which is considered the best of all Chinese carpet wools It is rarely obtainable in its pure type today

2 Mixed Sining wool is a mixture of true Sining and Kansu wool

3 Lanchow wool comes from the province of Kansu It is often blended with Tibetan wools

4 Szechwan (Szechuen) wools come from the province after which they are named and are classed with Tibetan wools

5 Woosung (Woozie) wools come from the neighborhood of Shanghai and are short in staple and suitable only for filling wools in carpet making They are known in the trade as one of the poorest carpet wools

6. Vicanere wool is produced in north central India and is one of the finest carpet wools. It is exceptionally lively and lofty.

7 Aleppo wool is grown in Syria, Asia Minor, and is considered one of the better class carpet wools It has good length and is well known for its color, strength, and resilience

8 New Zealand Romney wool is an improved type of wool similar in type to carpet wools but more uniform It is included in this study to represent a type of improved wool suitable for use in carpet manufacture. It is similar to the South American wools grown mainly by Lincolns, which are now furnishing a large part of the carpet wool imports to the United States

Chen established the main characteristics of these various samples and his results are tabulated in Tables 2 and 3

Burns, Johnston, and Chen have found certain definite relationships between objective tests in the laboratory and subjective tests by dealers and mills and these relationships have been incorporated in the following tentative guide of wool type for carpet wool producers

TABLE 2

PERCENTAGES OF EACH FIBER TYPE IN CARPET WOOLS, DETERMINED BY COUNTING AND WEIGHING

Wool Types	*Types of Fibers*							
	True Wool		*Heterotype*		*Kemp*		*Colored*	
	By Count	*By Weight*	*By Count*	*By Weight*	*By Count*	*By Weight*	*By Count*	*By Weight*
Romney	100.00	100.00	—	—	—	—	—	—
Lanchow	91.03	74.49	5.89	13.18	3.08	12.33	0.00	0.00
True Sining	88.65	42.84	9.14	46.19	0.12	0.23	2.09	10.74
Szechwan	87.12	57.65	5.80	27.85	7.08	14.50	0.00	0.00
Mixed Sining	84.66	61.51	3.93	16.42	11.35	22.02	0.06	0.05
Woosung	83.72	55.56	0.00	0.00	16.27	44.37	0.01	0.07
Aleppo	74.69	43.82	18.87	52.30	2.86	3.15	3.58	0.73
Vicanere	59.22	23.23	40.67	76.67	0.11	0.14	0.00	0.00

TABLE 3

FIBER THICKNESS AND LENGTH OF CARPET WOOLS

Wool Types	True Wool Fiber		Heterotypical Fiber		Kemp*	
	Thickness (microns)	Length Stretched (inches)	Thickness (microns)	Length Stretched (inches)	Thickness (microns)	Length Stretched (inches)
Romney	32	8 7	—	—	—	—
Aleppo	24	5 5	41	8 8	39 6	2 0
Szechwan	20 6	4 8	33 3	8 5	25 8	2 7
Lanchow	19 6	4 3	21 1	4 1	27 5	2 0
True Sining	17 5	4 4	36 3	8 5	—	—
Mixed Sining	17 4	3 2	32 4	7 8	28 4	2 4
Vicanere	17 4	2 9	25 7	4 7	—	—
Woosung	16 3	2 8	—	—	29 9	1 3

* Kemp thickness is arithmetic average of three parts of fiber

Tentative Guide of Wool Type for Carpet Wool Producers

1 An ideal carpet wool should contain at least 15 per cent by count or 35 per cent by weight of heterotypical fibers These fibers should have an average thickness of at least 30 μ, and the fiber sizes should not vary more than 15 per cent The average length of these fibers should be at least 4 in for normal growth (12 months), and the variability of the fiber length should be less than 20 per cent

2 An ideal carpet wool should contain not more than 2 per cent by count or 4 per cent by weight of kemp fibers The dimensional characteristics of the kemp fibers are not so important The important thing is to eliminate kemp from the fleeces, and this can be done, according to the experimental work carried out by Bryant (1933) working with Scotch blackface sheep

3 An ideal carpet wool should contain not more than 85 per cent by count or 65 per cent by weight of true wool fibers These fibers should have an average thickness not exceeding 25 4 μ, and their variation in fiber thickness should not exceed 25 per cent They should have an average length of at least 4 in for normal growth (12 months), and the variation in fiber length should not exceed 25 per cent

The principal geographical sources of carpet wools for the American market are British East India, Near East, including Iran, Armenia, Turkey, Iraq, Syria, Arabia, the North African countries, the British Isles, and South America Each of these geographical areas raises several different breeds of sheep suitable for carpet wool purposes, thus in any one area the quality characteristics of these wools and their values for carpet use vary greatly

The method of grading and marketing carpet wools differs in each geographical area In general there are two main classifications —shorn wool and pulled wool, and these are further divided into greasy wools and scoured wools The shorn wools are graded into different classes depending upon the country involved, such as fleece, second clip, lambs' wool, pieces and matchings, locks, tufts, brokes, crutchings, cots, and britch, and into color classifications of white, fawn, gray, mixed lots, etc

Table 4, worked out by Alexander Smith & Sons Carpet Co, gives some fiber characteristics observed in wools from the geographical areas:

TABLE 4

PRINCIPAL CARPET WOOL CHARACTERISTICS

	Average Fineness * *(microns)*	*Coeff of Variation (per cent)*	*Kemp (per cent by weight)*
New Zealand	30 0 to 40 0	20 to 30	1 to 4
China	20 0 to 30 0	30 to 75	1 to 10
British East India	25 0 to 40 0	25 to 50	1 to 30
Near East	25 0 to 35 0	30 to 45	1 to 8
North Africa	25 0 to 35 0	25 to 45	1 to 6
British Isles	30 0 to 40 0	25 to 50	1 to 15
South America	30 0 to 40 0	15 to 50	1 to 3

* Including true wool fibers, heterotypical fibers, and kemp fibers

In general the wools from South America and the British Isles and New Zealand are the coarsest and longest of carpet wools As can be seen from the variability of fiber diameter shown in the table above, the chief characteristic of carpet wool types is a wide distribution of fiber diameter within fleeces and lots, with the greatest variability in the China types and the lowest in New Zealand and South American breeds.

Blending of Carpet Wools

Length, strength, resilience, color, and loftiness of the fiber are the five main characteristics to be considered in wools for carpet pile yarns Since no one grade of wool contains all of these characteristics in the desired degree, it is common practice to blend several

grades of wool together to obtain these desired characteristics Another reason for blending wools of several districts is that the wool within a district will vary from season to season depending upon the weather and grazing conditions Thus, blending makes it possible by proper adjustment of the mix, to keep the yarn characteristics constant in spite of seasonal variations in the individual wools

Carpet Yarns

Woolen and worsted yarns used in carpet and rug manufacture are much heavier in size than those used in the wearing apparel industry Woolen clothing yarns may vary from 4 8 to 6 4 Typp* (3 to 4 run†), while woolen carpet yarns are usually 1 6 to 2 4 Typp (1 0 to 1 5 run) The same difference is noted in worsted yarns Worsted clothing yarns are spun as fine as 44 8 Typp (80s worsted count‡), while worsted yarns used in carpets are seldom finer than 9 0 Typp (16s worsted count) Table 5 gives the approximate counts, ply, strength, and twist of common carpet pile yarns

* Thousands of yards per pound
† Run number of 1,600 yard hanks of yarn per pound
‡ Worsted count—number of 560 yard hanks per pound

TABLE 5

DATA ON WOOLEN YARNS USED IN CARPETS AND RUGS

Grade	*TYPP*	*Run*	*Ply*	*Tensile Strength, Pounds**	*Twist in Ply per Inch*
AXMINSTER					
Light yarn	2 4	1 50	3	65	½–3
Medium yarn	1 9	1 19	2	40	½–3
Heavy yarn	1 7	1 06	4	200	½–3
BROADLOOM					
Light yarn	1 55	97	2	90	½–3
Medium yarn	1 9	1 19	3	110	½–3
Heavy yarn	1 7	1 06	4	200	½–3
JACQUARD					
Light yarn	1 82	1 14	2	80	½–3
Medium yarn	1 9	1 19	3	110	½–3
Heavy yarn	1 7	1 06	4	200	½–3
CHENILLE					
Light yarn	2 4	1 50	3	65	½–3
Medium yarn	1 9	1 19	3	80	½–3
Heavy yarn	1 7	1 06	4	200	½–3

* Skein break of 15-yard skeins wound on 1½ yard reel

Besides the woolen and worsted yarns used in the pile of carpets and rugs, there are cotton, jute, woolen, and even linen yarns used in making the back structure These yarns form the filling (weft) and warp The characteristics of these yarns are given in Table 6

TABLE 6

YARNS IN THE BACK STRUCTURE OF CARPETS AND RUGS

Type of Fiber Used	*Count**	*Ply*	*Number of Ends Used*	*Tensile Strength†*
FILLING YARNS				
Cotton	11's–4's	3–6	1–2	6–16
Jute	3½–21	1–2	1–2	10–27
Wool	1 6– 8	1–4	1	6– 8
Kraftcord (Typp)	1 0– 9	1	1	7–10
STUFFER YARNS				
Cotton	11's–4's	3–6	1–4	6–16
Jute	11–21	1–2	1–4	14–27
Wool	1 6– 8	1–4	1–3	4– 6
WARP YARNS				
Cotton	11's–4's	3–6	1–4	6–16
Jute	3½–21	1–2	1–4	10–27

* The counts used in each case is the count for that fiber, namely
Cotton—number of 840 yard hanks of yarn per pound
Jute—the weight of 14,400 yards of yarn
Wool and Kraftcord—Typp or thousands of yards of yarn per pound

† Tensile strength is given as the single end break

Besides the more common yarns listed in the table, sisal, ramie, paper, and other yarns are used in the manufacture of summer and porch rugs

Weaving and Construction of Wilton Carpets

The filling, warp, and "stuffer" yarns actually form the back structure of the carpet and constitute the "weave" The filling (weft) yarns are those yarns running across the width of the fabric, while the warp and stuffer yarns lie lengthwise in the fabric The warp yarns are split into two sections, alternating warp ends being threaded through alternating harnesses in the loom, thus with the two warp harnesses in the high and low position respectively, a V-shaped opening called the "shed" is formed The filling yarn is inserted through this opening or shed The stuffer yarns are actually warp yarns that lie lengthwise in the carpet However, they are not

used primarily to bind in the filling yarns as are the warp binder yarns, but rather to give the fabric body or handle

The Jacquard Loom

The Jacquard loom, which is used to manufacture Brussels and Wilton carpets, is limited as to the number of different colors required in forming the pattern Warp and stuffer yarns for Jacquard weaving are wound on large spools or beams Each beam runs across the whole width of the loom, the number of ends on the beam being equal to the pitch (number of ends in the width) of the fabric which is to be woven For example, a three-quarter 256 pitch fabric with a double warp and a three-end stuffer will have 512 ends on the warp beam, and 768 ends on the stuffer beam (See page 718)

These yarns are sized before winding on the beam to impart stiffness to them and subsequently to the carpet, and to reduce the chafing on the yarns as they pass through the loom harness and heddles during the weaving process This process of warp sizing is known as slashing and the machine used in applying the size is called a "slasher"

The filling or weft yarn is wound into small packages which fit into the loom shuttle These packages, called "cops," are sized, and conditioned to high moisture content, and the yarn woven into the carpet

The pattern of the fabric is controlled through the Jacquard mechanism by the Jacquard card (Fig 1) These cards are punched with the proper distribution of control perforations by highly skilled operators working from the design pattern Each card controls the 2 to 6 frames of pile tufts appearing in one row of pile tufts across 9 inches of carpet Sufficient cards are prepared to control the rows in one entire repeat of the pattern

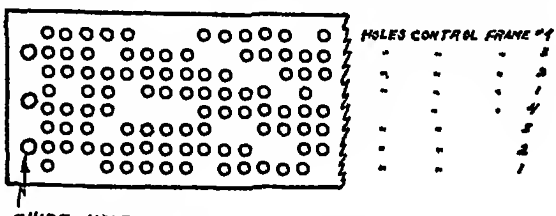


Fig 1 Section of Jacquard card

The card shown in Fig 1 is actually divided into two sections to give more strength The first and fifth longitudinal rows of holes control the first frame (color) of pile yarn, the second and sixth rows, the second frame,

etc. The fifth frame on the Crosley Jacquard is automatically controlled. Wherever the other four frames are not used for a tuft of a row, the fifth frame is drawn into the pile surface. Referring to the card, the pile tufts would appear in the carpet (from left to right) as follows:

End 1—5th	frame or color	End 16—4th	frame or color
2—5th	" " "	17—1st	" " "
3—1st	" " "	18—3rd	" " "
4—1st	" " "	19—3rd	" " "
5—1st	" " "	20—3rd	" " "
6—5th	" " "	21—3rd	" " "
7—3rd	" " "	22—2nd	" " "
8—3rd	" " "	23—2nd	" " "
9—4th	" " "	24—2nd	" " "
10—1st	" " "	25—2nd	" " "
11—4th	" " "	26—1st	" " "
12—4th	" " "	27—5th	" " "
13—4th	" " "	28—4th	" " "
14—4th	" " "	29—1st	" " "
15—4th	" " "	30—1st	" " "

Note. This description applies directly to the Crosley type Jacquard. The Halton type Jacquard is similar in principle although different in several details.

The pile yarn, usually woolen or worsted, is wound onto small individual bobbins or spools which will be placed in the frames or racks behind the loom. Each bobbin holds about 7 ounces of yarn (approximately 275 yards). One frame holds as many bobbins as there are ends of pile yarn in the width of the carpet. Therefore, if a carpet is 36 inches wide and has 8 ends per inch (pitch of 8), there will be 8 x 36 or 288 bobbins or spools in the frame. Jacquard fabrics are usually woven with two to six frames of pile yarn. Each frame of yarn is usually one solid color, although different shades may be placed in a frame to give the effect of more frames thus making a more colorful pattern. This is known as "planting."

When a loom is set up for weaving, the frame spools or bobbins are placed in their creel as desired. Figure 2 shows a three-frame Wilton fabric. The pile yarn is placed in the frames A, B, C, and then threaded through their specified harness G_1, G_2, G_3, then through the reed and onto spike roll K. The warp and stuffer yarns are threaded through harnesses F_1, F_2, F_3, and then through the reed and onto the spike roll. The three-frame fabric as shown will have six strands of yarn in each reed dent or space—three pile yarns, two warp yarns, and one or more stuffer yarn ends.

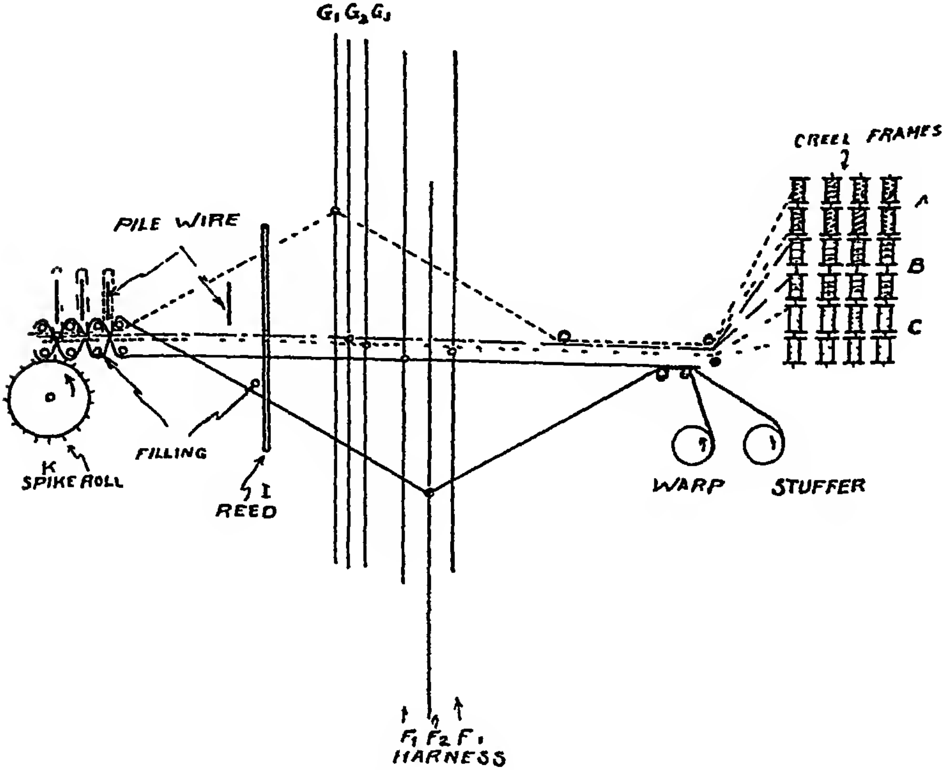


Fig 2 Diagram of Jacquard carpet weaving

Figure 3 shows a cross-section of the Jacquard head mechanism Jacquard cards A or "Jacquards" are in a continuous chain revolving around hexagonal cylinder B The cylinder is perforated at each position for possible holes in the card The cylinder presses the card against needles C, which are lined up so that there is one needle for every frame at every position on the loom Some needles will contact blank or unperforated positions on the card Some will pass through a hole in the card, into the cylinder, and therefore do not move in relation to the leveling board

Wherever a needle strikes a blank space in the card the needle is displaced and pushed toward the leveling board, displacing the eye in needle D, which carries harness cord I so that knot F in cord I will be caught in lash board E, when the lash board is raised Cords which have been caught in the lash board are raised carrying with

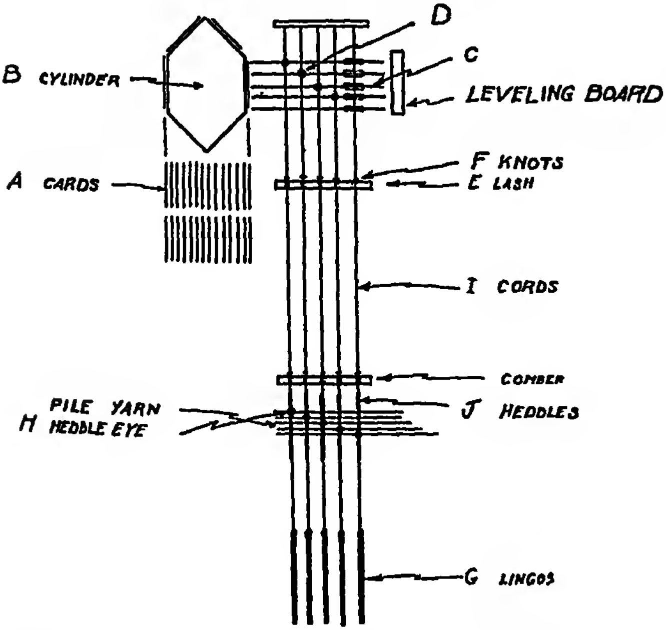


Fig 3

Details of heddle control in Jacquard loom

them the respective yarns which they control while the remaining yarns lie in the back structure with the stuffer yarn When the selected yarns are raised, a "pile wire" is inserted in the shed and, as the cords and their respective yarns are subsequently dropped, a loop is formed over the wire

After several more rows are woven to insure a bind, the wire is withdrawn leaving the yarn which had been looped over it as pile. In Wilton weaves the loop is cut as the wire is withdrawn In Brussels carpet the loop is not cut Figure 2 shows a three-frame Wilton with the first frame yarn G_1 forming the pile tuft and the other two frames G_2 and G_3 are woven into the back of the carpet

The comber board is used to raise all five frames simultaneously when the bottom filling shot is inserted

Figure 4 shows cross-sectional views of Wilton carpets Carpets and rugs are usually designated as "two

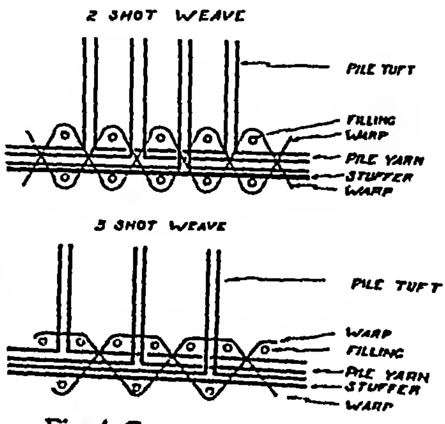


Fig 4 Cross-section of two-shot and three-shot Wilton weaves

shot" or "three shot," depending on the number of picks or "shots" of filling yarn to each row of pile yarn.

Velvet and Tapestry Carpets and Rugs

Velvet and tapestry rugs in past years were generally figured or patterned rugs, but in rug form today these are not as popular as patterned goods of Axminster and Wilton types The velvet drum-dyed pattern types are still pre-eminent in installations of long-wearing carpet in pattern form in public buildings and theaters Velvet looms today are used primarily for weaving one-color fabrics

The yarn for plain velvet carpets and rugs is dyed normally in the raw stock form, that is, before the raw wool is carded or spun into yarn or in the skein Raw stock dyeing is preferable for large lots as it is possible to get a level color over a very large batch of yarn As much as 100,000 pounds of wool is dyed one color and then blended, carded, and spun into yarn It is possible to obtain uniform shades by proper blending and picking of the dyed batches If the yarn of the plain velvet is dyed in the skein form, the normal batch size is around 1,000 pounds, although larger batches are possible with special equipment

Those velvet and tapestry fabrics woven with a pattern for commercial carpet use are manufactured by dyeing the desired colors on the yarn before it is woven

White yarn is wound on large cylinders or drums The circum- ce of the drum is equivalent to the length of the yarn necessary weave one warpwise row in the length of the rug, or for one pat- rn repeat in the carpet The drums range from 4 to 18 feet in di- eter The yarn is wound in such a way that its strands lie side by de in a single sheet across the entire width of the drum One drum of yarn must be printed for each warpwise row in the width of the fabric. For a 9 foot wide fabric having eight warpwise rows per inch (8 pitch) there must be 8 x 108 or 864 drums of yarn printed As a full drum will hold upward of 800 complete parallel, and hence duplicate, ends of yarn, the yarn printed will be used in 800 rugs, or if the pattern is symmetrical about the center, in 400 rugs

Beneath the printing drum is a truck or carriage which holds a

color pot containing dyes mixed into a paste with starches and gums Freely revolving in the color pot is a wheel which presses against the yarn when the carriage is driven across under the drum The turning of the drum is controlled by the operator. The drum is rotated to appropriate positions as indicated by the design, and while in each position the color is applied in bands of widths just sufficient to correspond with the length of one tuft A complete revolution of the drum is made in applying one color where it is required The color carriage is then changed and the next color applied at the proper points of the circumference It is common practice to apply the light colors first, then the dark colors, and finally black This reduces any tendency of the colors to run

After the drum of yarn has been printed, the yarn is separated into skeins, removed from the drum, and placed in long shallow screen-bottomed trays The trays are placed in steamers where application of wet steam sets the color All traces of the starch and gum from the printing paste is then thoroughly washed away by revolving the skeins in a bath of soap and water After drying and winding, the spools are stored until required for beaming

One skein from each drum is placed on a creel frame in position to form the desired pattern and the yarn is wound onto the loom beam The greatest care must be taken that the pattern is in register, or matched Of course, differences in stretch of individual yarns tend to alter the lengths of the printed color bands thus tending to throw the pattern out of registration Usually the beaming machine is stopped and the pattern matched at the start of each rug, or every 25 feet, for short, repeat-pattern carpet

As has already been stated, there is little difference between the Wilton and the velvet looms, except that there is no Jacquard mechanism on the velvet loom The velvet loom is primarily a single shuttle, plain and flat loom with cam-driven harnesses The yarn is wound on a single beam similar to the warp and stuffer yarn, rather than on a series of small bobbins placed at the back of the loom

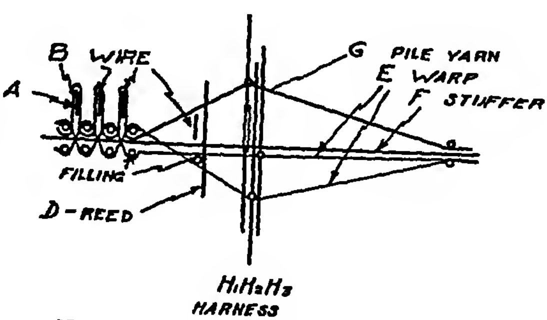


Fig 5 Diagram of velvet weaving

Figure 5 is a cross section of a typical velvet fabric showing pile A as woven into the fabric with pile wires B still in the loops of the pile yarn, filler C, reed D double warp E, which work in harnesses H_2 and H_3, and stuffer F, which works through the same harness as the pile yarn in harness H_1.

Figure 6 shows a cross-section view of two- and three-shot velvet constructions.

The stuffer in velvet carpets sometimes contains colored yarns, cotton jute, or woolen to simulate a Wilton back Some figured velvet carpets up to 9 feet wide and rugs up to the 9- by 12-foot size are produced by weaving the velvet carpet either in greige or in all-over colors and then printing with intaglio engraved rolls in print machines similar to the calico print machines except that they are considerably larger in size After printing the carpet is aged in an ager and then dried.

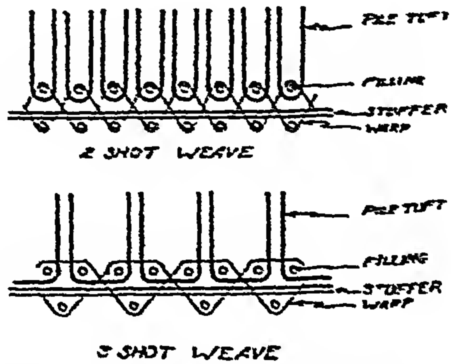


Fig. 6 Cross section of two-shot and three-shot velvet weave.

Axminster Carpet

Axminster fabrics are woven on looms, which, although they have some of the characteristics of the Wilton loom, still have become sufficiently different through American invention to separate them into a different class Axminster looms have long spools on which the required number of ends of yarn are wound to supply the tufts across the pattern in one row Ends of different color are selected and arranged in the same order along the spool as they are to appear across the row of carpet This operation of winding the loom spools is known as "setting."

The setting is usually done first on 27- or 36-inch-long spools, and if the loom is wider than this, two, three, four, or even more spools are joined together to make up the required width The machine employed in winding the spools is known as an Axminster setting frame The setting frame consists of a bank or tray of spindles to hold the spools of supply yarn representing the required

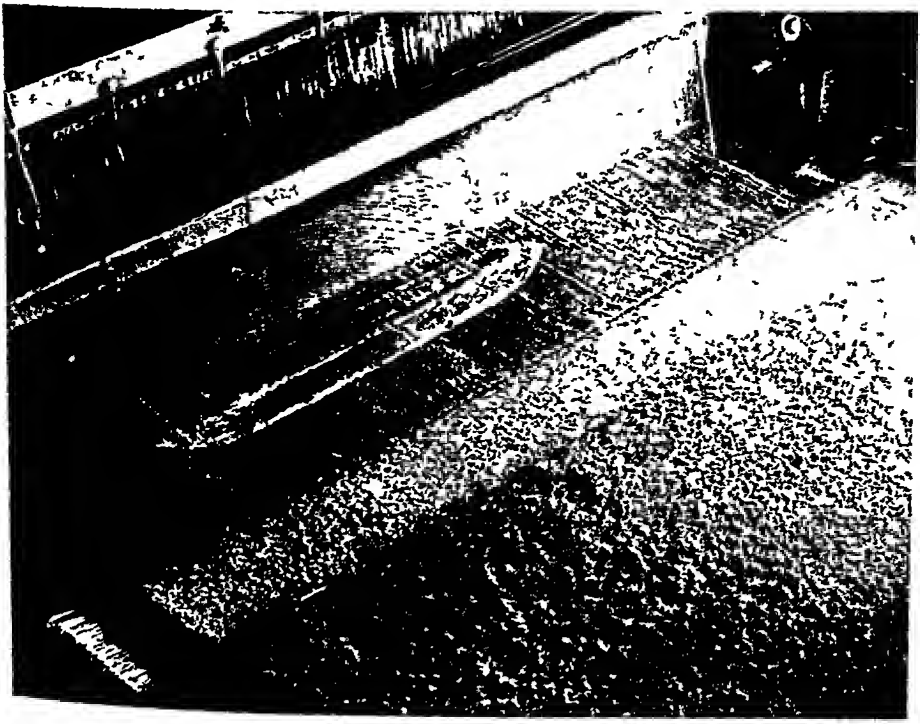


Fig 7 Velvet loom showing shuttle in shed

(*Courtesy Bigelow-Sanford Carpet Company, Inc*)

colors, a series of reeds to hold the ends of yarn in any predetermined order, and a mechanism to wind the yarn on the setting spool in the chosen combinations and order along the length of the spool

Working directly from the painted design, the operator (setter) places on the first spindle a spool yarn of the color represented in the *first* tuft in the first row of the design paper, on the second spindle a spool of yarn of the color represented by the *second* tuft in the first row of pile; and so on until yarn spools have been placed on the spindles for each tuft of yarn represented by the first row of the design paper The yarn ends are then threaded through the reed in their correct order and wound onto the setting spool Usually 22 feet of each end of yarn is wound on each spool This is sufficient to weave 250 to 275 repeats of the pattern

After all the setting spools for a pattern have been wound, they are placed in loom frames or tube frames, and each individual end threaded through a separate tube. These tubes serve to separate and

guide the yarns as they are inserted into the fabric. The tube frames are placed between two endless chains

Figure 8 shows the four primary types of Axminster weaves regular, two-plane, Imperial, and Oriental (pattern-through-to-the-back).

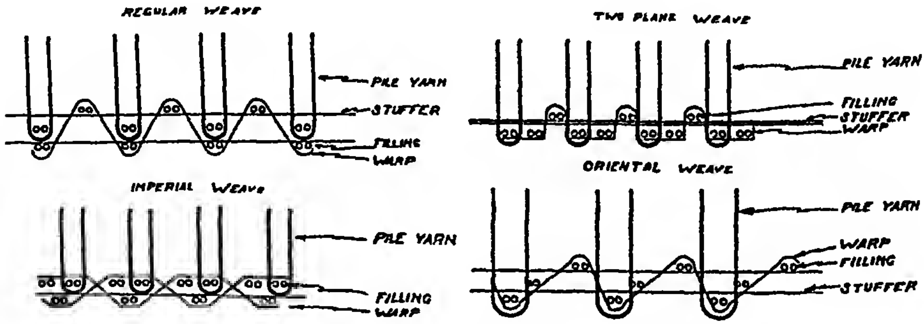


Fig 8 Diagrams of Axminster weaves

An early English-type Axminster loom which is still used to some extent has a Jacquard to select the pile The disadvantages of this loom over the American type just described are that fewer colors can be used in forming the design, and that machine speeds are slower

For weaving on the Jacquard Axminster loom, the yarn is wound on bobbins and placed in frames as for Wilton weaving The Jacquard is controlled by cards the same as the Wilton loom The pile yarn from the bobbins is threaded through a series of eyes in slats Each slat represents one warpwise row of pile tufts, and has five or six eyes in a vertical row through which the pile yarn ends are threaded from the five or six frames of yarn behind the loom In weaving, the Jacquard, controlled by cords as on the Wilton loom, raises or lowers the slats so that the correct color is raised to position in a single line across the loom A series of grippers grasp yarn from this line, draw off a tuft length of each end, hold it until cut, and then insert the yarn into the fabric

Chenille Carpet

Chenille carpet is similar to Axminster carpet in that there are unlimited color combinations possible in forming the pattern Chenille is unique in that the rows of pile tufts are formed previous to being inserted into the carpet

The pile yarn is woven on a flat loom (chenille blanket loom) using fine cotton warps and woolen filling yarn The warp yarns are placed in groups of six and each group is spaced some distance apart The distance between the groups of warp yarns governs the length of the tuft in the finished carpet The filling yarn used on the flat loom is the woolen or worsted yarn which will become the pile yarn in the finished carpet The filling yarn is wound into cops and used in shuttles as usual in a plain, flat-weave loom Each shot of filling represents one potential tuft of yarn

The blanket is made up weaving pick after pick of woolen yarn in the various colors as determined by the pattern As in the Axminster setting the operator works across the colored design, changing his shuttle each time the color in the design changes The blanket has as many filling yarn picks as there are to be tufts in the width of the finished carpet The rows per inch on the blanket loom vary from ten to twenty or more depending upon the quality to be woven, and the size of the yarn employed The cotton warps are usually woven with a "leno" weave to bind the pile yarn more firmly

A blanket is woven for each row in the lengthwise repeat of the pattern of the finished carpet After the blankets are woven they are passed through a machine with revolving knives, which carefully cut the blanket into strips Great care must be taken to cut the blanket exactly in the center between the groups of binder warp yarns The cut strips are then moistened and passed over a grooved roll, which by heat presses the flat bands of "fur" into a V-shape ready to be used for a row of pile tufts

The second loom used in the manufacture of chenille carpet has a fine "catcher" warp, a "chain" warp, and the usual "stuffer" warp The stuffer warp is usually coarse woolen or jute yarn, while the other warps are cotton

The loom is actually a flat loom except that the chenille fur is bound in by the catcher warp to form the pile Usually there are two to four shots of filling yarn in the back or basic weave to each row of chenille fur that is bound by the catcher warp The chenille fur is entered into the fabric while the catcher warp is raised, and the loom stopped, and the fur set to match the preceding row, and combed to stand upright Usually four to eight rows of fur are inserted per inch

Reversible chenilles These rugs, usually bath mats, are made similar to regular chenille rugs except that the fur is not folded into a V-shape after cutting, but is woven flat so that the pattern appears on both sides of the finished fabric—hence its name

Punched Felt Rugs

During the last few years a new type of rug—the punched felt rug—has increased greatly in popularity. This is an inexpensive rug having a design printed or stenciled onto a punched felt. The felt is usually made with a jute or hair web on each side of a light burlap. The felt "loom" consists of a board containing rows of barbed needles, which are rapidly and repeatedly pushed through the web and burlap. The barbs on the needles catch the fibers and push them through the burlap, thus binding the entire web to the burlap. The felt is then passed through a hardener, which by heat and pressure flattens and smoothens the surface. Adhesives are applied to increase the bind of the fabric, and to improve its "handle."

The design may be applied by a rotary printer, similar to, but much larger than, those used in printing cloth (the print rolls must be 12 feet in circumference for printing 9- by 12-foot rugs), or may be printed on a flat-bed printer.

Flat Weave Rugs

These rugs are used mainly on porches and sunrooms during the summer months. They are woven on flat shuttle or needle looms. They are made using hemp, sisal, ramie, jute, grass, wool, cotton, paper, or similar yarns.

Nonraveling Carpet

A type of velvet-construction, plain-color carpet in various textures has been developed in more recent years as a construction which permits cutting of the carpet to any desired size or shape without raveling. The pile yarn is woven through to the back and the carpet is coated on the back with an adhesive which binds the fabric securely together. Patterns are formed by sealing abutted edges together with tape and cement. This permits of special designs of individual patterns, such as seals, coats of arms, or patterns especially designed for an irregular shape of room.

Finishing of Carpets

All carpets and rugs receive several finishing processes after weaving before they can be shipped from the mill. They are closely inspected by burlers or "pickers," who insert any missing or misplaced

tufts, repair any broken warp, filling, or stuffer yarns, and in general eliminate the minor errors, which always take place in the weaving

The carpets are then sheared A shearing machine has revolving, spiral knives which rotate tangent to a flat knife blade, similar to the action of a lawn mower This cuts all the projecting yarn ends and leaves a smooth, flat, pile surface After shearing the carpet is steamed to open and brighten the pile surface

Axminsters and the lower-grade Wilton and velvet fabrics are back-sized, using a starch or dextrine size to improve their body or "handle" It has become general practice to coat small Axminster mats with a rubber compound so they will not slip on the floor

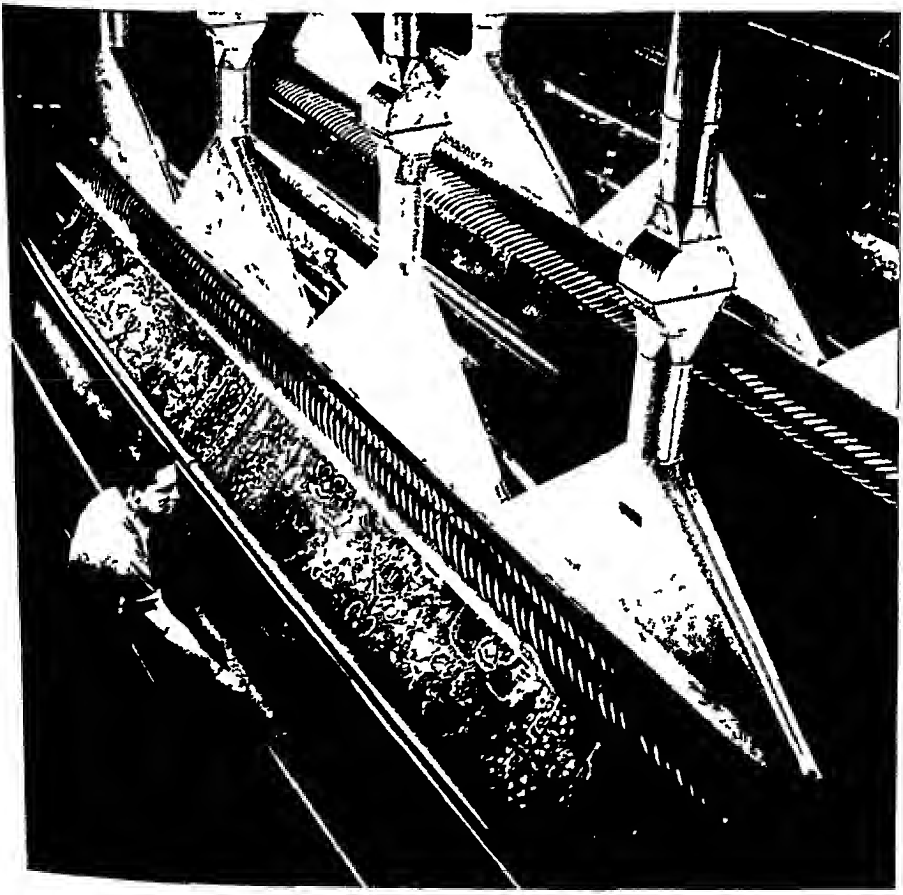


Fig 8 Double width carpet shears
(*Courtesy Bigelow-Sanford Carpet Co, Inc*)

Chapter 22

THE MANUFACTURE OF FELTS

NON-WOVEN FELTS

By Niran Bates Pope[1]

History of Felt

NON-WOVEN, or pressed felt is probably the most ancient form of a wool textile fabric and was the material to follow animal skins as protective garments Loose, matted wool from wild sheep was collected, pressed into solid masses and used as clothing by primitive man Authorities believe that it constituted the first fabricated wool clothing. It was probably made by plucking wool from the hide of a slaughtered sheep, laying it on a flat stone or other level surface and pounding it while damp until a fairly solid sheet was produced Layer upon layer were added to secure thickness of the felted and matted mass The mat was then rolled by foot pressure

Evidence of the early use of felt has been found in the nomadic tribes of central Asia, who used it for tents as well as clothing It furnished protection against wind and rain and yet was easily rolled up and transported Later it was used as a floor covering to replace rushes and coarse straw mats Felts of this type also made early religious and ceremonial headdresses. It appears that felt was known in India as early as 325 B.C. Marco Polo, the Venetian, reported that the Mongols of the thirteenth century made circular felt-covered tents and covered their carts with black felt tarpaulins to keep out the rain. The Chinese considered white felt to be peculiarly sacred The Greeks used felt for a head covering and, later, as lining for helmets, as well as for heavy rain-proof garments Julius Caesar employed felt as a shield against arrows and as a covering for wooden raiding towers and other military equipment History mentions a light brigade of Caesar's which was equipped with breastplates of felt A complete felt-making plant was discovered in the ruins of Pompeii

To this day, primitive tribes of the desert—Mongols and Berbers—still use felt for clothing and tents and make it by almost the same crude

[1] The Felt Association, Inc, through Korbel & Colwell, Inc

where the first mechanical wool carding machine in America was installed back in 1793—adapted itself particularly to the manufacture of sheet felt in 1897, and was later succeeded by the Byfield Felting Co. The same year also witnessed the founding of the Eastern Felt Co. at Winchester, Mass.

In 1898, the Taylor & Bloodgood Felt Company at Rahway, N. J., the Tingue House Co. at Glenville, Conn., the City Mills Felt Company at Norfolk, Mass. and the Alfred Dolge Felt Company at Dolgeville, N. Y. combined and became the American Felt Company. Later, they included the Waite Felt Company of Franklin, Mass.

S. Stroock & Company, which had been felt distributors for some years, started manufacturing felt in 1899 at Newburgh, N. Y., the same year that the Western Felt Works went into the field. The Lawrence Felting Company, Federal Felt Company, Standard Felt Company, and Danbury Felt Company were organized subsequently. In 1910, the Faatz-Reynolds Felting Company, the Bowden Felting Mills at Millbury, Mass. and the Nelson-Dedicke Company of Middleville, N. Y. combined and became the Felters Company.

The Felt Association was formed and, at the present time, practically 90 per cent of the felt business in the United States is represented in its membership. This group includes four manufacturers of flat or roll felts, four members of the sheet felt and felt wheels division, and five jobbers and cutters.

Definition of Felt

The word "felt" covers a complete range of materials from linings, pads and soft fabrics to tough, boardy sheets up to 3 in. in thickness, and includes polishing wheels used in the metal industries.

The product which is known simply as "felt", its traditional name, but often incorrectly described as "pressed felt," may be defined as follows:

Felt, wool—A fabric built up by interlocking fibers by a suitable combination of mechanical work, chemical action, moisture, and heat, without spinning, weaving, or knitting. It may consist of one or more classes of fibers, wool, re-processed wool and/or re-used wool, with or without admixture with animal, vegetable and synthetic fibers.[2]

Felt as defined here does not include punched, woven, synthetically bonded, stitched, quilted, paper or other materials of felt-like appearance, which are products of entirely different construction.

[2]Revised definition approved by the Felt Association, Inc., September, 1945, accepted tentatively by American Society for Testing Materials (Section D on Felt, of Sub Committee A 3), March, 1945.

Fiber content Felt manufacture calls for an expert knowledge and use of a greater variety of fibers than any other single branch of the textile industry. This fact is indicated by the types of raw stock required by the industry as shown in Table 1. The felting tendency is a physical property peculiar to wool which, more than all other fibers, has this kinking ability together with the toughness necessary for rough handling. These virtues, moreover, last as long as the fiber itself, so that wool, new or reprocessed, is the matrix of felt mixtures. The felting tendency will vary, however, with the grade and staple of wool fiber. It is present in such high degree in the more readily felted wools that they will bind-up to 80 per cent of nonfelting fibers into a thoroughly integrated, permanent, but random construction. Lower-grade felts, in which cost is a primary consideration, may include the by-products

deadening and heat insulation, as in airplane construction, wool-kapok felt is used An abrasive felt will consist of wool mixed with cotton fibers, and goat hair, etc.

TABLE 1 RAW STOCKS USED IN THE WOOL FELT INDUSTRY IN 1942

Type of Raw Stock	*% Total Fiber Processed*
Wool, reprocessed and reused	33
Wool, virgin (48 types)	18
Noils, Noble and French	10
Card waste, woolen and worsted	5
Cotton, raw domestic, India, China	11
Cotton merinos	10
Rayon waste	6
Hair, cattle and goat	5
Vegetable fibers (kapok, ramie, jute)	1
Miscellaneous (silk, viscose and acetate rayon, Vinyon, Aralac, etc.)	1
Total	100

Blending or picking After the fibers are chosen, the wool is scoured to degrease it, and frequently de-pitched and carbonized. Designated proportions of specified wools, or wool with other fibers, are then weighed out according to batch requirements The mix, or blend, is spread on the floor in layers until the batch is complete It is then hand-fed into the mixing-picker, a machine which mixes, stirs and re-shuffles the fibers The stock is run separately through the mixer and then into a bin, where it is blown and swirled around as a fluffy mass until the fibers are thoroughly opened up and uniformly blended

Carding and fabricating. After picking, the blended raw stock is put through a breaker card equipped with a Bramwell, or other automatic weighing feed From the breaker, an Apperly automatic feeding system delivers the roving to a standard type wool finisher card further to blend and comb the fibers The finishing card, or "former", as it is often termed, delivers the stock in web formation to an endless 42-yard forming apron The forming apron delivers batts ranging from ¼ to 1 in. in thickness and 36 to 80 in in width (Fig. 1.)

The customary method of fabricating "roll" felts, or those made in 42-yard lengths, is to cross alternate webs from multiple-card sets to provide transverse, as well as longitudinal strength "Sheet" felts, which are the thicker, high-density types, are fabricated in smaller pieces to satisfy practical milling requirements and are frequently formed on a Blamire lapper card, with successive batts crossed by hand laying These batts are laid up in considerable thickness, sometimes to as much as 3 ft.

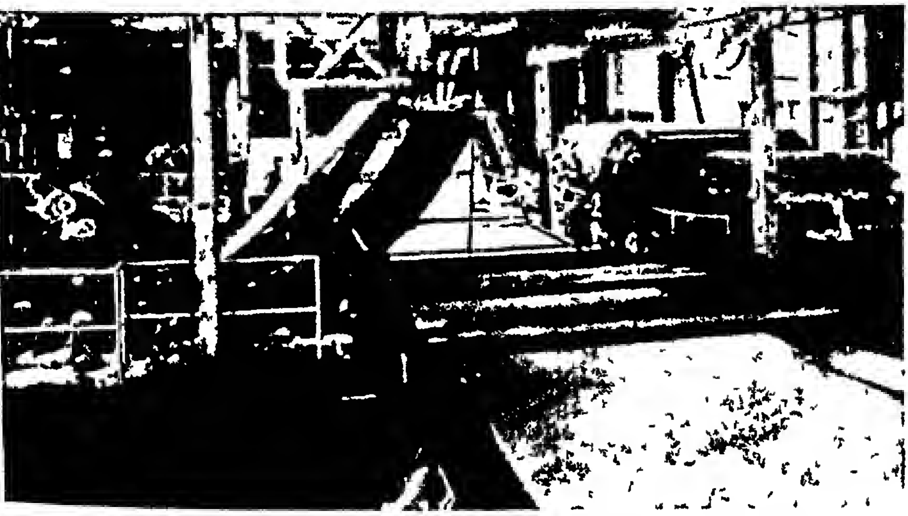


Fig 1 Six-cylinder white goods carding set for wool felt Consists of four breaker cylinders, one finisher straight card and finisher crosser card to the left (*Courtesy The Felt Association, Inc*)

Hardening. The batt has now arrived at the operation which is peculiar to felting and which has no direct parallel in the textile, or any other, industry The object of this hardening process is to give the batt enough consistency to permit easy handling in the subsequent fulling process.

The batt is put onto the lower platen, or plate, of a heavy press (See Fig 2) This plate is of varying dimensions to accommodate the different sizes of batt An apron of burlap, properly moistened, is laid over the batt and other batts are piled on top of the first one until the desired weight and thickness is reached Steam is now turned on and the pieces saturated The top platen of the press is then let down onto the hot, moist blanket and the machinery is started The top platen oscillates rapidly, rubbing the upper surface of the batt against the fixed bed of the machine and causing the surface fibers to penetrate the mass and set up cross-bonds between the layers which make up the batt The hardening process will reach its limit when the interlocking of the fibers can proceed no further under interfacial pressure and vibration.

At this point, the manufacture of roll felt and of sheet felt diverge *Roll felts* are made usually in 40 yd lengths, 60 or 72 inches wide and are carried through the hardener in two first-run and two second-run batts after the preliminary steaming The first-run batts are those hardened first They act as a cushion in the final hardening of the

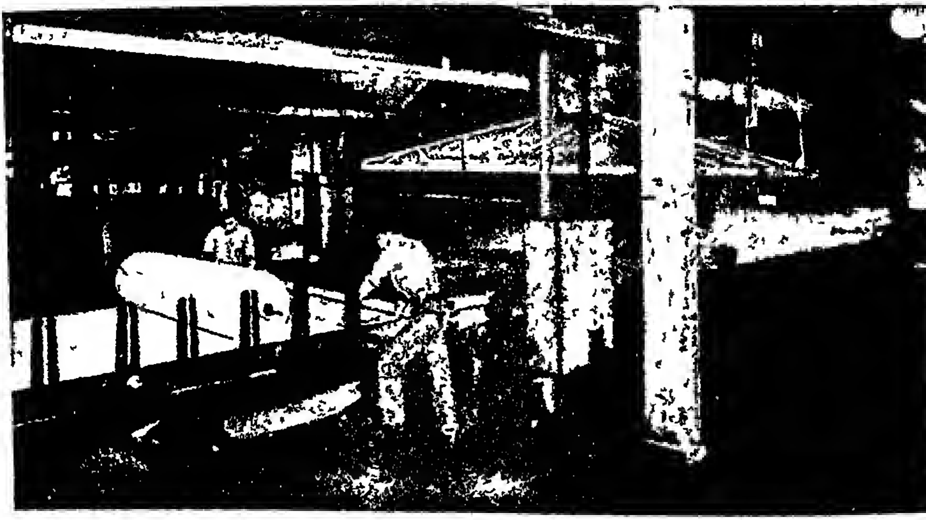


FIG 2 Hardener on which carded batts are laid is at right of machine. After passing over the steam chest and under the plate the batts are rolled up for the next process of fulling (*Courtesy The Felt Association, Inc*).

second-run batts In the complete felting process, roll felts are reduced in thickness from a maximum of 6 inches to 1 inch *Sheet felts,* being more highly compressed are formed into thicker batts, ranging up to 3 feet for a sheet that is reduced to 3 inches The size of the batt will depend on the desired type of finished sheet

Fulling. Most of the fulling action is carried out by means of direct and controlled impact in the conventional one-, two-, three-, and four-hammer mills (See Fig 3) These mills are bin-like receptacles with plano-concave breasts, opposed to which are wooden impact hammers having stepped faces which conform roughly to the contour of the breast Driven by crank or eccentric mechanism, the hammers roll, lift, pound, and squeeze the felt batt against the breast, then allow it to fall back, and turn it so that a different face is presented for the succeeding power stroke (For the action of fulling, see Chapter 3, Physical Properties of Wool) Prior to fulling, the hardened batt is treated with a fulling agent which serves as a lubricant during the operation and is subsequently removed For the lighter felts, warm water is sufficient For soft-finished pad and millinery felts, 1 part of palm-oil soap to 10 parts of water is preferred. Very dense, heavy-duty mechanical and glass-polishing hair felts and felt wheels are most readily fulled with the assistance of a 4° Twaddell solution of sulphuric acid This treatment is known as acid fulling

Fig 3 Fulling white wool felt The hardened felt is being laid in the door (the heavy wood shown immediately in front of the left hand operator's leg), which is raised and the hammers put into operation
(*Courtesy The Felt Association, Inc*)

After treatment with the appropriate fulling agent, the felt is folded and rolled in a definite pattern to obtain the desired width and lengthwise shrinkage, and loaded in the fulling mill Fulling continues for periods of three minutes, for lightweight felts, to twelve hours or more for hard-felts, sheet and wheel felts. Periodically during the process the felt is removed from the mill, straightened, pulled to remove wrinkles and prevent it from felting upon itself, and then refolded and replaced for further milling Dimensional shrinkages attained by fulling approximate 10 to 20 per cent for pad weights, 40 per cent for back checks (the hardest grades of roll felts) and 75 per cent for hard-sheet felts

After fulling, the felt is scoured and neutralized to remove residual soap, dirt, grease, or acid It is then dyed, if required, any water is

extracted, and it is dried Roll felts are dried under tension in a circulating hot-air drier at temperatures of 140° to 220° F. When required in a specific density greater than that obtained from maximum milling, sheet felts are further compacted in hydraulic presses. For extremely dense sheets, such as the "hard" and "rock hard" qualities, pressing is a definite supplement to fulling and a part of the manufacture, as distinguished from an ironing, or finishing, treatment

Finishing. For certain purposes felts are left rough as they come from the driers Others are pressed, sheared on the surface to remove long fiber ends, or, in the case of some of the harder felts, run through a drum sander that is surfaced with garnet paper (See Fig 4.)

In addition to dyeing felt in a full range of colors, the common practice for millinery and other specialty uses, wool felts are frequently impregnated with various protective treatments These include fire-retardant, mold-proofing, moth-proofing, water repellent, and other treatments

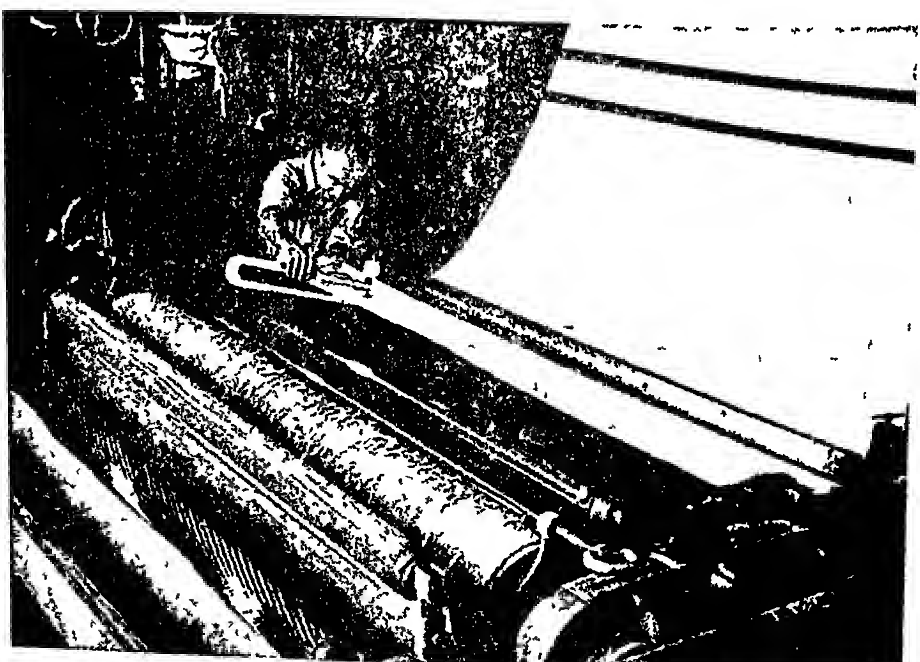


Fig 4 Firm felts finished by sanding and brushing to give smooth surface and controlled thickness Thickness variations are held to thousandths of inch (*Courtesy The Felt Association, Inc*)

An entirely different class of felt treatments is the application of substances to modify the physical characteristics for specific purposes. Such treatments include stiffening or hardening by sizing, or impregnation with special compounds. Treatment with thermoplastic resins permits the felt to be stretched or pressed over a form and then permanently stiffened by heat forming.

Mechanical felt parts, such as liquid seals for shafts and ball bearings, are often cut from felt laminated with one of the rubberlike materials. Gaskets and other parts subject to severe exposure may be given a range of coating treatments or impregnations with latex or one of the synthetics.

Felts for Mechanical Uses

Because of the uniform dispersion and random orientation of the fibers, wool felt possesses two unique characteristics which make it adaptable to the fabrication of mechanical parts.

The *first* special property is uniform wear, which adapts wool felt as a covering for metallic and other surfaces as a protection against dents, squeaks, and scratches. For frictional uses, the fact that wool felt never becomes threadbare ensures uniform performance throughout the life of the part.

The *second* special property is that wool felt does not ravel or fray, no matter in what direction it may be cut, but cuts to an accurate edge in any pattern. Hence, roll and sheet felts are commonly die-cut to blueprint patterns and dimensions in three-decimal tolerances, also skived to bevels, and laminated by stitching or adhesives to form undercuts and special contours. Circular wicks are extruded through revolving dies. Sheet felts are bored, turned, and carved to form parts for machines of many kinds, even in the manufacture of artificial limbs.

Felt Standards

Something like 80 per cent of the wool felts produced are now manufactured under an inclusive program of standardization. The basis of this program includes the standard types and qualities of felt required for automotive uses as originally adopted by the Society of Automotive Engineers in 1923. These standards were developed by the S A E with the cooperation of the Standardization Committee of the Felt Association, Inc., in co-ordination with the standard test methods of the American Society for Testing Materials.[3]

[3] Society of Automotive Engineers, *Felts, SAE Standard*, ASTM Designation D-461.

THE MANUFACTURE OF WOVEN FELTS

By R K. Brooks

The manufacture of woven felts started in the United States about 1864 However, at that time the industry had been brought to a comparatively high state of perfection in England and other European countries, and until the close of the Civil War all woven felts used in the United States were imported In those days the utility of woven felts was not so well known as it is today and for the first few years the growth was slow With the increased use of machinery, felts came to be used in the printing and lithographing trade for innumerable anti-vibration purposes, for polishing stone, glass and wood, in the manufacture of pianos and in other ways and for purposes too numerous to mention Today there are ten or a dozen concerns manufacturing woven felts in the United States, many of them specializing for certain industries

Woven felts, whatever the purpose, are extremely durable Resiliency is a valuable characteristic in certain types, resistance to changing atmospheric conditions distinguish other types, others are valuable for their fine finish and uniform thickness and still others for their frictional qualities The larger woven felt mills are devoted to the manufacture of paper makers' felts, covering for tennis balls, filtering cloths and goods of various kinds for piano manufacturers Some of the largest consumers of woven felts are cotton mills, chemical and dye manufacturers, electrical goods manufacturers, furniture manufacturers, hat manufacturers, lithographers, newspapers, marble manufacturers, optical lens makers, printing press manufacturers, piano manufacturers, silk mills, thread manufacturers, tennis ball manufacturers, typewriter manufacturers and woolen and worsted mills

As machine manufacturing operations increased in number and variety and as dimensional precision became more important in efficient operations, it was necessary continually to improve this system of manufacture so as to produce standard articles The strides made from the day of the hand loom to the woven felt-making machinery of today is a story of marvelous accomplishments It has been truly said that the manufacture of woolen fabrics and, particularly, woven felts, requires more intensive study and continued vigilance than almost any other product of modern ingenuity From the beginning of the processes to the turning out of the finished product, of which there are thirty-five individual steps and as many minor

ones, a thorough practical and skillful knowledge of mechanics, chemistry, designs, colors, weave, dyes and finishes is required

Raw materials. To select the right kind of wools for the various processes, an intimate knowledge of both foreign and domestic wools is required The manufacturer of woven felt must know what kind of wools are to be blended to produce the best goods for specific purposes In selecting wool special study must be given to the fineness and length of fiber, strength, elasticity, color, luster, felting and shrinking qualities While American wools are selected for certain woven felts, Argentinian and Australian wools are needed for other types Then there is an infinite variety of blends necessary to obtain other specific results in the finished product In fact, each and every grade of wool must blend with other grades to secure the desired effects in finished woven felt

Mixing and blending Although the importance of proper methods of mixing stock before subjecting it to the carding process is often underrated, it may be stated that the character of the goods ultimately produced depends, to a great extent, on the manipulation of the stock at this point Mixing is the blending, or amalgamation of different qualities of wool, and is resorted to for various purposes in different mills The main problem is to produce a standard line of merchandise year after year from wools which constantly vary Therefore, the blending of wools, i e —the selection of various qualities, grades and fineness requires scientific study, the constant attention and experience of experts

Dusting and burr picking After the wools are blended to just the right proportions of each kind to obtain the best results for the various types, the blends are placed in dusting machines where the loose dust and dirt are removed In this process the wool is passed over rolls with spiked teeth and a blower system carries away the dust and lighter foreign matter Following this the wool goes to a large and rather complicated machine, which removes the burrs and other clinging vegetation The wool is then ready for the important process of cleansing

Scouring. This is a process that requires the skillful use of water of the correct chemical properties that will not injure the fiber. It is the final major cleansing process and also serves to open it up ready for the subsequent process of carding Scouring consists of immersing the wool in various tanks where a series of rakes with teeth of varying lengths separate the wool, keep it moving onward slowly and subject it to a thorough cleansing proc-

ess The last tank is for rinsing and from there the wool goes through rollers, which squeeze the water out. Then the wool goes to the drying machine where fans blow hot air through the wool as it rests on an endless wire conveyor The wool is now light in color, white and fluffy, and is blown by a fan through huge pipes to the bins near the carding machines

Carding The wool is carded with the greatest care and transformed into what, to the novice, appears to be an endless band of soft loose fiber This includes an operation called "roving" as it comes from the machines and is wound on spools ready for the spinning room

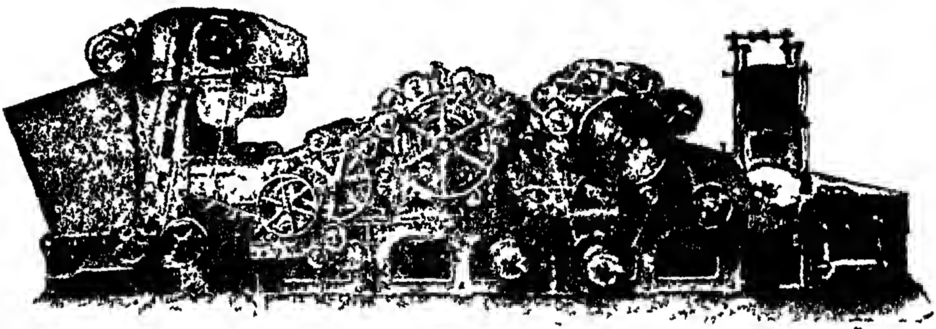


Fig 5 Breaker felt card with all-metallic wire clothing on cylinders, broad band delivery and automatic feed

At the back of each card is an automatic feeder in which the wool is placed by the feed-tender The wool is received by the feed-rollers that act very much as a spool does when strands of hair are wound around it and they in turn pass the wool with a rolling motion along to what is known as the first breaker, where the carding actually commences The modern carding-machine has huge cylinders on which are thousands of wire teeth that at one time or another perform the task of seizing the fibers presented and tearing the lumps apart and partially straightening them This process employs not only one set of rolls and cylinders, but several—the main cylinder in every case being the heaviest worker, acting not only as a bottom card for every roll, but performing besides the duties of carrier as the wool is conveyed from one roll to another

The process through which the carded wool is passed before its final preparation for spinning is a sideways motion that rolls the wool into a roving The roving that is gathered automatically from

the cards resembles a fluffy white web of fibers This is separated into smaller strands and wound on spools preparatory to spinning

Spinning. Before spinning, extremely delicate tests are made to determine the weight of the roving and also the moisture content, for while the wool is in the soft fluffy condition of the card room, atmospheric conditions have a considerable influence. In the carding and spinning rooms humidifying systems are installed which, to a great extent, offset changes in weather conditions

When the roving comes into the spinning room it is loose and fluffy. The process of spinning consists of transforming this roving —loose fibers of wool—into yarn by drawing and twisting. The process also winds the yarn on bobbins The operation of spinning is performed by a machine called a spinning mule, one of the most ingenious machines ever invented.

The spinning-mules are multiple machines, drawing, twisting and spooling the yarn from a large number of roving spools at the same time The operations are performed rapidly and simultaneously by the spinning-mule The operator, or spinner, places the roving spool at the back of the mule and guides the end of roving to the bobbin or spindle. The spindle carriage then moves away from the roving spool just far enough to stretch the roving to a desired length When the carriage stops, the spindles twist the roving, the carriage returns to its former position and while it is moving backwards the spindle revolves and winds the stretched and twisted roving, now "yarn," on itself The process is then repeated The length of stretch, and the number of twists, all have a direct bearing upon the character of the finished goods In determining those factors the spinner must also take into consideration the quality and length of the wool fiber (For greater detail on mule spinning see Chapter 11)

Weaving Weaving is the process of interlacing yarn, or threads of wool in such a manner as to produce a fabric The weaving machine or loom varies in construction according to the kind of fabric to be produced Fundamentally, weaving is a comparatively simple process but as the material required becomes more refined and the purposes of its use more exacting, so does the weaving process become more complicated In some cases special looms are built for one purpose and still other special looms for other purposes This makes it possible to produce goods of varying qualities, construction, weight, etc , goods which, when finished,

give the desired results Mills that manufacture woven felt make from thirty to fifty different kinds of material on different kinds of looms, hence it is a specialty business

The looms must be the most modern, ingenious and efficient that can be built Each loom is adjusted to weave a certain number of threads to the square inch, some goods requiring a much closer weave than others This is one of the most interesting processes in the manufacture of woven felts (For details of looms see Chapter 16)

Fulling or milling process. When the goods come out of the looms they bear very little resemblance to the finished product For instance, some cloth which may appear to be coarse with the weave plainly discernible as it comes from the loom, will, when finished, have a beautiful surface with the weave invisible to the naked eye This transformation is accomplished through various highly specialized operations, one of the most important of which is the fulling or felting process The fulling process transforms it into material known as woven felt However, after coming from the loom and before commencing the fulling process, the goods are carefully inspected They are spread on long, window-lighted tables so that practically every inch may be examined for possible weaving imperfections

Fulling or felting, the process from which woven felts receive their name, is the method of utilizing that peculiar property of the wool fiber, where one fiber interlocks with another and in doing so shrinks until the full width of the piece of cloth becomes very much less than its woven width The three agencies through which this process most readily takes place are heat, friction, and moisture, and it is in providing more efficient means of applying these agencies that the development of fulling-machinery has been made Fulling-mills consisted of large hammers suspended over a tub and alternately dropped on the fabric, until the advent of the modern fulling-mill which receives the woolen goods in a long string and by continuous motion passes it while in a moist condition through heavy rollers The results desired have always been the same, namely a thickening and strengthening of the fabric, the increasing of its wearing qualities and the reduction of its heat conductivity (For a more detailed description of fulling see Chapter 19)

Finishing In order to remove the oil and dirt that have accumulated during the preceding processes, the woven felts are now washed in tubs After the washing and while still wet, the goods are put through a process of napping on machines having large

rollers covered with teasles Teasles are the seed-pods of a plant and have sharp, springy points which have never been imitated successfully Following this the goods are dried and then sheared, which cuts off excessive surface fibers

The last process is ironing or pressing, so necessary to give and maintain an even finish and thickness It serves to smoothen out and reveal the scientific accuracy of construction in all of its dimensions The goods are then carefully inspected, tested for strength or thickness, length, width, and weight and marked for grade, customer and use

There are many types of woven felts, each being made to meet different technical requirements Such felts are known by various special names, such as bushing cloth, sticker cloth, whippen cloth, damper-lever-cloth, butt cloth and key rail cloth, all used in the piano industry. Specially developed woven felts are tennis ball cloths, printing-press-cloths, filter cloths for gases, chemicals, water and air; slasher cloths, dresser cloths used by the worsted spinners; roller cloths for spinning, drawing and comber rollers, clearer cloths, felts for polishing optical lenses, hardening cloths for the hat making trade and a wide variety of cut felt products where thousands of yards of woven felt are cut into washers, strips, and pads of special predetermined sizes and shapes

TABLE 1 COMPARATIVE TABLE OF MOISTURE CONTENT AND REGAIN (IN PERCENT)

Moisture	*Regain*	*Moisture*	*Regain*	*Moisture*	*Regain*
7.0	7.5	10.7	12.0	14.4	16.8
7.1	7.6	10.8	12.1	14.5	17.0
7.2	7.7	10.9	12.2	14.6	17.1
7.3	7.8	11.0	12.4	14.7	17.2
7.4	8.0	11.1	12.5	14.8	17.4
7.5	8.1	11.2	12.6	14.9	17.5
7.6	8.2	11.3	12.7	15.0	17.6
7.7	8.3	11.4	12.9	15.1	17.8
7.8	8.4	11.5	13.0	15.2	17.9
7.9	8.6	11.6	13.1	15.3	18.1
8.0	8.7	11.7	13.3	15.4	18.2
8.1	8.8	11.8	13.4	15.5	18.3
8.2	8.9	11.9	13.5	15.6	18.5
8.3	9.1	12.0	13.6	15.7	18.6
8.4	9.2	12.1	13.8	15.8	18.8
8.5	9.3	12.2	13.9	15.9	18.9
8.6	9.4	12.3	14.0	16.0	19.0
8.7	9.5	12.4	14.2	16.1	19.2
8.8	9.6	12.5	14.3	16.2	19.3
8.9	9.8	12.6	14.4	16.3	19.5
9.0	9.9	12.7	14.5	16.4	19.6
9.1	10.0	12.8	14.7	16.5	19.8
9.2	10.1	12.9	14.8	16.6	19.9
9.3	10.3	13.0	14.9	16.7	20.0
9.4	10.4	13.1	15.1	16.8	20.2
9.5	10.5	13.2	15.2	16.9	20.3
9.6	10.6	13.3	15.3	17.0	20.5
9.7	10.7	13.4	15.5	17.1	20.6
9.8	10.9	13.5	15.6	17.2	20.7
9.9	11.0	13.6	15.7	17.3	20.9
10.0	11.1	13.7	15.9	17.4	21.1
10.1	11.2	13.8	16.0	17.5	21.2
10.2	11.4	13.9	16.1	17.6	21.4
10.3	11.5	14.0	16.3	17.7	21.5
10.4	11.6	14.1	16.4	17.8	21.6
10.5	11.7	14.2	16.6	17.9	21.8
10.6	11.9	14.3	16.7	18.0	21.9

rapid method for determination of moisture content in wool This forced-draft wool dryer has four individual heating chambers, permitting simultaneous drying of four samples of as much as 400 grams each in thirty minutes or less Each of the four heating chambers is provided with a rotary pump and heating unit The design of the apparatus is such that the heated, filtered air is forced continually through the wool in the specimen container Thermoregulators control the temperature to

$\pm 2°$ C., and the rotary pumps force 13 cubic feet of air per minute through the wool.

The wool containers supplied with the apparatus are made of alum-

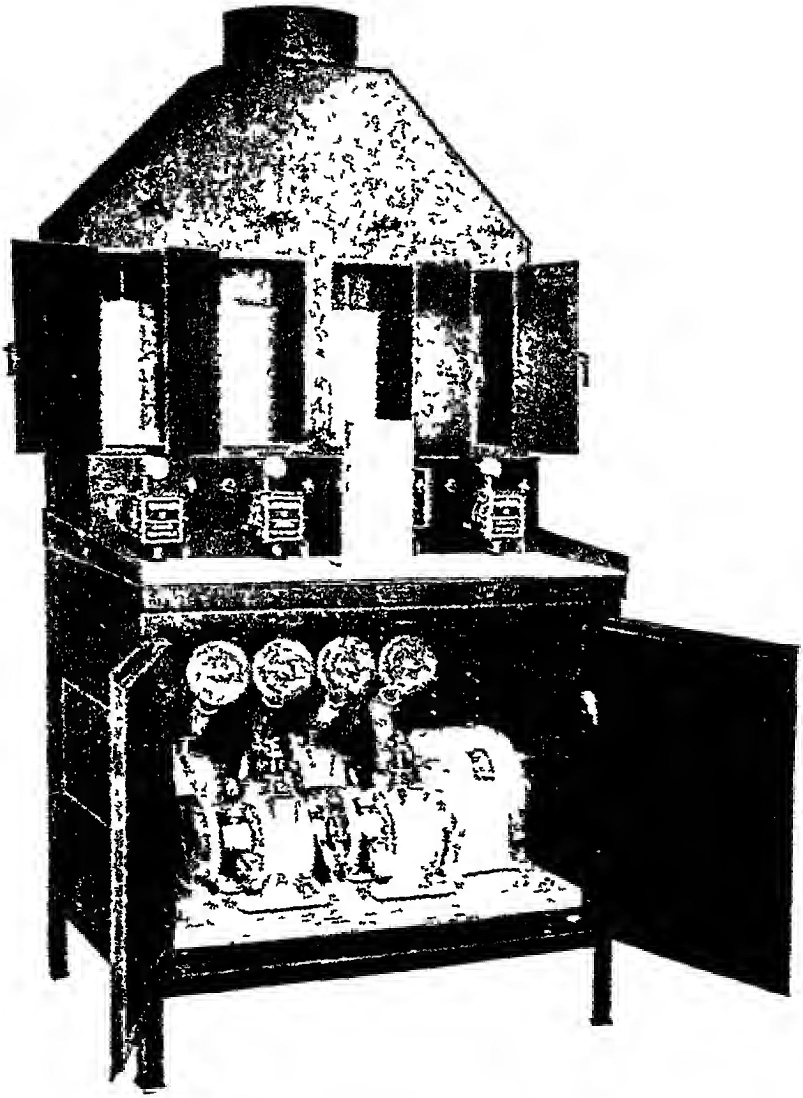


Fig. 1 Baird wool dryer. (*Courtesy Baird Associates.*)

mum with a perforated metal disc in the bottom to hold the wool in the container and a perforated pressure plate inside the drying chamber on top of the wool sample to prevent it from blowing out under the blast of air Aluminum caps are provided for both the tops and bottoms of the containers after they are removed from the oven

Maximum capacity of the standard container (5 in x 10½ in) is 250 grams (9 oz) of dry wool For wet wool having about 60 per cent regain, i e , scoured wool just after centrifuging, the sample may be as large as 400 grams (14 oz) For wool top having about 15 per cent regain, a sample of 280 grams (10 oz) may be taken

The samples are weighed before and after drying in the container itself which has been adjusted to a standard weight For accurate results, 15 minutes must be allowed for cooling before weighing

Even though more rapid moisture determinations are possib'e with this equipment, there is still a definite need for instruments capable of establishing the moisture content within a few minutes Various electrical instruments have been on the market but, for the most part, they have not been able to withstand rigorous mill use The most satisfactory instruments work on alternating current and measure the dielectric property of the wool Since this property varies directly with the moisture content, it can be used to determine the moisture in wool

Fiber Testing

Wool fiber testing is necessary to study the physical properties comprising the quality of the fiber, as discussed in Chapter 3 The main fiber characteristics which have a decisive influence on the quality of wool are fineness, length, strength and elasticity

Fineness The fineness of the wool fiber is judged in the trade mainly by visual inspection This is inadequate for many purposes, and precision methods have been developed in recent years Two physical methods have found wide application the micrometer caliper method and the weight-length ratio for determining the diameter

The *micrometer caliper* method was first used by Hardy and further developed by Burns and others The basis of this method is the use of a watchmaker's micrometer caliper, with an enlarged barrel to facilitate reading the graduations It has been proved fairly accurate and the measurements obtained bear a rather close relationship to the microscope measurement

The *gravimetric* method developed at the Wool Industry Research Association in Leeds, England, is based on the ratio of the weight of

the fibers to their length The method consists essentially of weighing a counted number of fibers cut to a definite length This method gives very good results when the fibers are free from air-filled medullae When the medulla is present, the weight length ratio gives a result much finer than the diameter as measured microscopically Both of these methods are far more cumbersome than the microscopic methods to be described later

Length. The ordinary method of establishing the staple length of raw wool is simply by measuring with a ruler the length of the individual staples as grown Because of the crimps present in raw wool, such a measurement does not represent the actual length The actual length of the *straight* fiber, i e, crimps removed, is measured by two distinct methods, either individually or in groups

For single fiber testing the Wilkinson *tuft* method is used In this method a cotton thread, guided by a needle, is looped around a bunch of fibers and tied tightly with a slip knot This bundle or tuft of fibers is then extracted from the test specimen The tuft is freed from all loose fibers before the cotton thread is opened Then all fibers present in a tuft are pulled out individually with the help of tweezers and measured in a stretched condition, with both ends held by tweezers

For large scale testing, as is necessary for determining the average

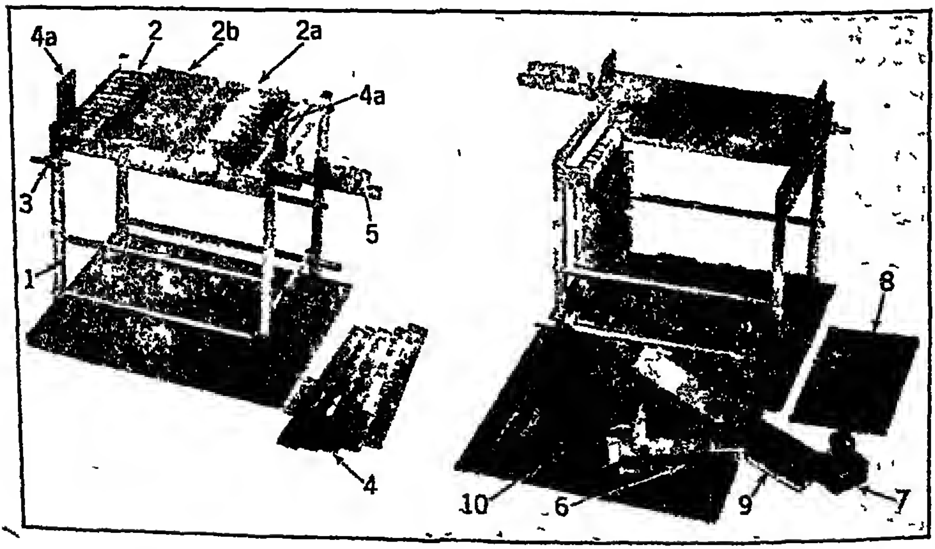


Fig 2 Wool fiber stapling apparatus (*Courtesy A Suter*)

lengths of top, this method is too cumbersome and machines have been devised to facilitate the testing of groups of fibers The most widely used procedure is the one developed by the wool section of the American Society for Testing Materials, which is based on the use of a wool fiber stapling apparatus shown in Fig 2.

The stapler, which is capable of segregating the longer fibers into half inch groups and the shorter into quarter inch groups, consists of the following parts: (1) a frame (2) two series of parallel *faller* bars pivoted at one end, the greater number set one-half inch on centers and the lesser number one-quarter inch on centers, each bar being fitted with a set of long (2a) and a set of short (2b) needles, (3) a removable supporting rod to permit dropping the bars held by racks 4a, (5) a small combing bar, attached at the front of the machine, (6) an adjustable fiber clamp, (7) a depressor, (8) a faller bar lifting plate, (9) a ruler, and (10) a plush-covered board.

The working procedure for this instrument was described in A S T M Designation D 519-40 and re-approved in 1946 without change From the results obtained a curve can be drawn expressing the distribution of lengths. Typical curves are given in Fig 3.

There are several automatic stapling machines available The best known instrument suitable for the length determination of wool tops is the Schlumberger stapling machine which was adopted by the Bradford Conditioning House in England

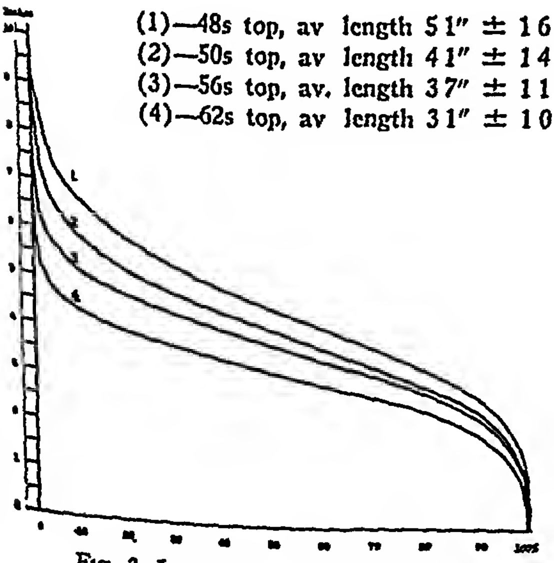


Fig 3 Length curves of wool tops

Strength The strength of a wool yarn and ultimately of the fabric, depends to a large extent on the tensile strength of the fibers of which the yarn is composed For example, a mohair yarn will always be stronger than a wool yarn of the same number In addition, the strength of yarns man-

ufactured from short length fibers is strongly influenced by such factors as fiber friction, staple length, fineness and yarn twist Worsted yarns, for instance, are generally twice as strong as similar woolen yarns because of the more parallel arrangement of the fibers In the final analysis, the original fiber strength remains the basis for the strength characteristics of a finished wool product

Because of the great strength variation from fiber to fiber the testing of single fibers is a very tedious process The small dimensions of the fibers necessitate apparatus quite delicate in construction A number of such apparatus have been developed as reported by Schwarz and Fox[1]

The most recent single fiber tester is the Sookne-Harris fiber extensometer shown in Fig 4 This instrument is based on the principle of an automatic Chainomatic balance, which produces an ink-drawn record of the load-elongation characteristics of the fiber In addition to

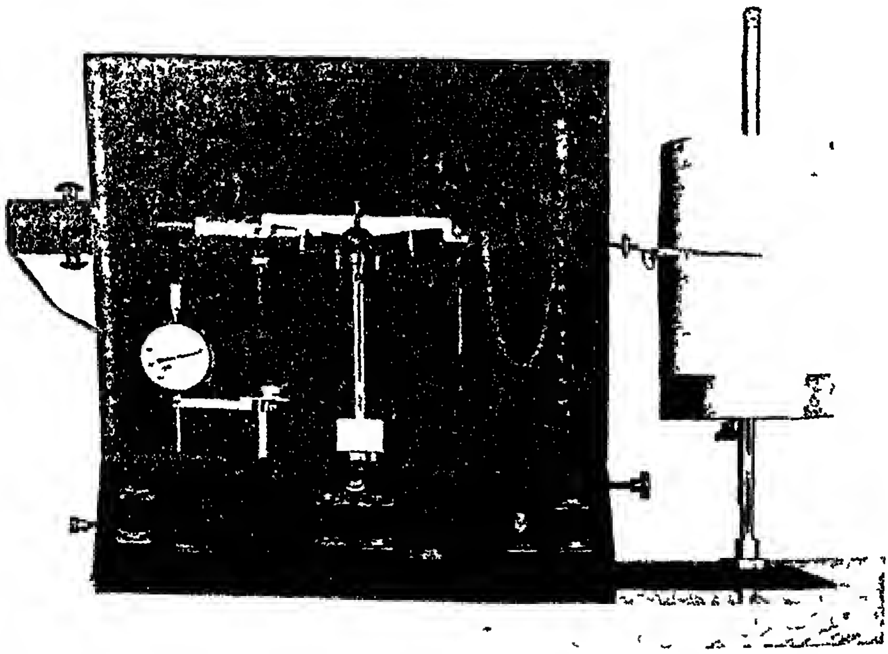


Fig 4 Sookne-Harris fiber extensometer (*Courtesy Harris Instruments, Inc*)

[1] Matthews-Mauersberger, *Textile Fibers*, (5th ed , New York John Wiley and Sons, Inc , 1947) pp 1060-1080

the load-elongation curve to the break, one or more hysteresis cycles can readily be obtained to permit the study of a fiber's ability to recover from extension Relaxation curves, in which the rate of *decay* of tension at a constant elongation is studied, are likewise within the scope of the instrument With slight modification, the apparatus is also capable of providing measurements of the folding properties, especially flexibility and resilience, of light-weight fabrics, or the compressional properties of pile fabrics at very low pressures

The testing of single fibers as a daily routine procedure is too cumbersome and can be shortened considerably by testing a great number of fibers at the same time The test method is known as the *flat bundle fiber test* A procedure described by Bellinson[2] has found wide application for testing wool top and roving The chief advantages of the flat bundle tests are the speed with which results can be obtained and the inexpensive equipment required

The machine required is a pendulum type breaking strength tester The technique developed for testing worsted tops at the Forstmann Woolen Company Laboratory is as follows:

Preparation of test specimens Small fiber bundles are drawn from the top in the same manner as for fiber length determination These bundles are put together and then carefully combed to straighten the fibers and to remove any fibers below a certain length The combed specimen is then trimmed with a razor blade to one-, two- or three-inch tufts, depending on the average length of the fibers. The tufts are then weighed, the weights being kept within the following limits to reduce probable error. for one-inch length, 30 milligrams, for two inches, 60 milligrams, and for three inches, 90 milligrams, plus or minus 10 per cent

The cut and weighed tufts are then mounted between adhesive tape Two strips of adhesive tape are placed ⅛ inch apart with the adhesive side up on a wooden board, 25 by 5 by 1 inches (Fig 5a) The tape is held in position by three rows of needles across the width of the board The prepared bundles are then laid across the two tapes with two inches between bundles, (Fig 5b) Two additional strips of tape are then laid carefully on top of the fiber bundles and coincident with the lower tape (Fig 5c). This tape is then pressed down firmly with the palm of the hand The bundles are marked for identification purposes and the tape between the bundles is cut with a razor blade (Fig 5d).

One bundle is then broken for the purpose of adjusting the apparatus

[2] Bellinson, H R, *Textile Research*, 8 (1938), pp 421-8

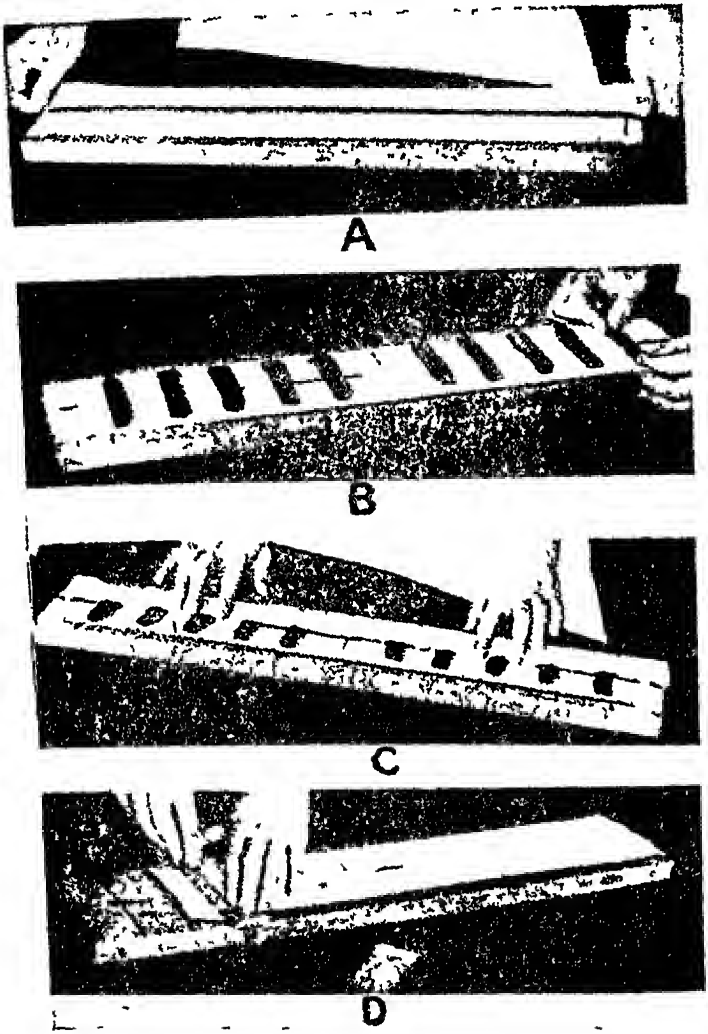


Fig 5 Preparation of bundles for tensile strength test (*Courtesy Forstmann Woolen Co*)

The lower jaw is raised until the two jaws are approximately 1/16 inch apart The bundle is then placed in the jaw so that the ends of the tape are level with the inner-face of the jaw and the fibers are aligned at right angles The test is then performed in the normal manner

The breaking strength of the bundle is then either converted into a strength per unit fiber or a strength per unit area, such as psi or kg/-sq cm

Yarn Testing

Yarns are generally tested for yarn number, twist, breaking strength and moisture regain A.S T M has developed two standard methods of testing yarns, namely, A S T M Designation D 403 for woolen yarns and D 404 for worsted yarns These methods include all of the above tests and their tolerances

To establish the *yarn number*, a yarn reel and grain scale are neces-

sary. For short lengths of yarns the Suter Universal yarn numbering balance is very useful

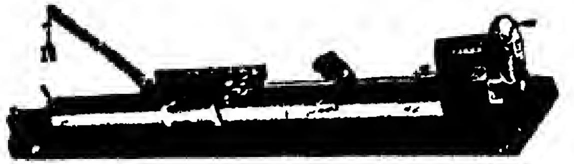


Fig 6 Twist counter (*Courtesy A Suter*)

To analyze the *twist* of yarns the A.S.T.M. method specifies the use of a twist counter Various instruments of similar constructions are on the market, one of which is shown in Fig 6 The twist is normally expressed in turns per inch and the direction of turns (S or Z) is given at the same time

The *breaking strength* and elongation of yarns are determined by two distinct methods, 1) the skein method, and 2) the single strand method

In the *skein* method, a standard skein of 120 yards wound on a 1½

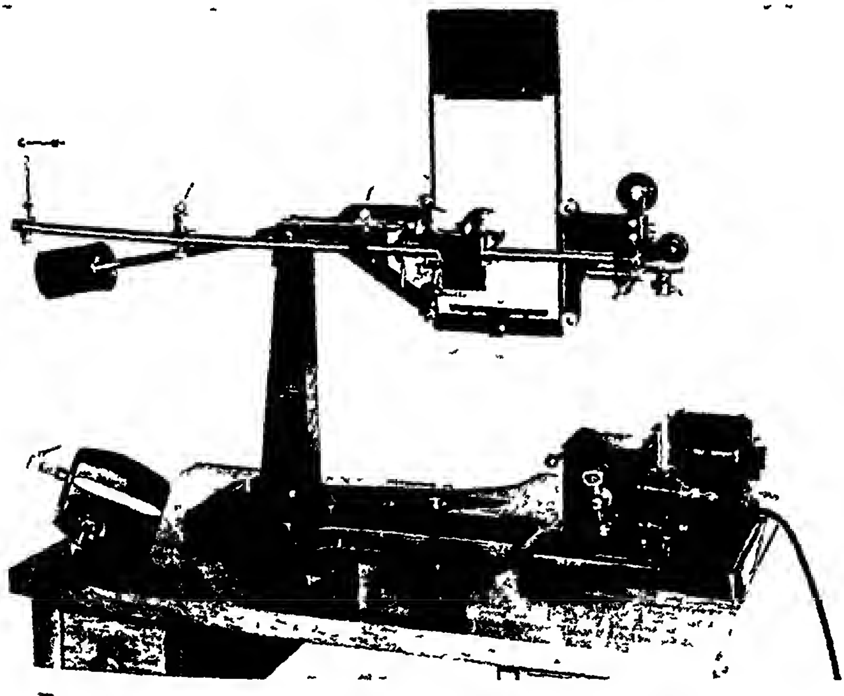


Fig 7 Serigraph—Model IP-2 (*Courtesy Scott Testers, Inc*)

yard reel is broken on a skein tester. In the *single strand tester,* 20 inches of yarn are clamped in suitable jaws and broken The strength is recorded in ounces or grams and the elongation in per cent. The official instruments used are of the pendulum type

The instrument shown in Fig. 7 is the *serigraph,* which applies to the specimen a definite amount of load per unit of time through the use of the incline plane principle Instruments of this type have the added feature that hysteresis or fatigue may be determined at any predetermined point of load for any number of repeated cycles Continuous strength and elongation testers have recently been developed

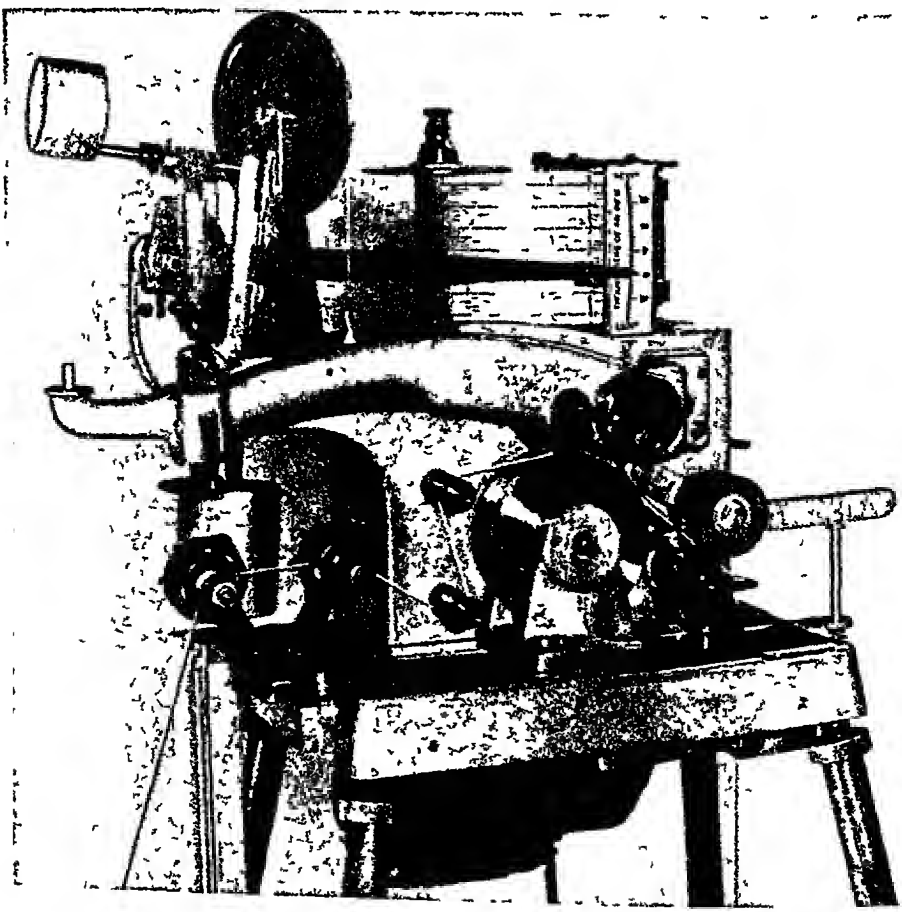
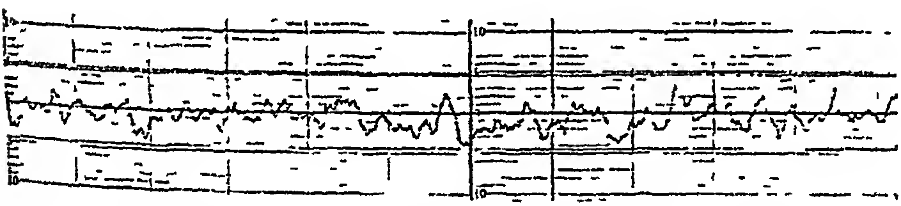


Fig 8 Sliver Tester (*Courtesy Pacific Mills-Worsted Division*)

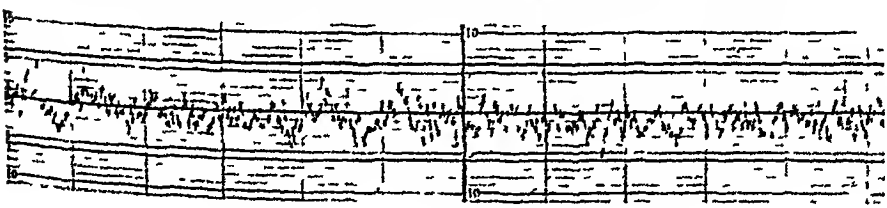
Evenness of yarn is commonly observed by winding the yarn on black cardboard in seriplane panels The Pacific sliver and yarn testers developed recently record simultaneously, by means of thickness measurements at constant pressure and tension, both the evenness and the weight of a given length of sliver or yarn (Fig 8)

The *sliver* tester has a capacity of from 3½ ounces per 5-yard length of wool top or sliver (i e , 12,250 grains per 40 yards) to a fineness of 7 5 hank roving (i e , 66 7 grains per 40 yards) Top or sliver of any other fiber in this size range and some slivers heavier than 3½ ounces per 5 yards, such as those of rayon, can be tested Also, yarns heavier than 1/7 5s worsted count may be tested on this instrument

The *yarn tester* has a size capacity of from 1/7 5s to 1/60s worsted count Yarns of all fibers or mixtures of fibers in this size range can be tested Heavier yarns can be tested on the sliver tester Both the sliver and the yarn tester have a number of grooves, and record accurate results regardless of atmospheric conditions and moisture, oil or finish content of the sliver or the yarn itself



a Worsted yarn 1/36s worsted count 008″ groove "X" scale



b Woolen yarn 5-run 012″ groove "X" scale

Fig 9 Thickness variation in a worsted and a woolen yarn as recorded by the Pacific yarn tester (*Courtesy Pacific Mills Research Laboratory*)

In Fig 9 are shown the graphic records of a 5-run woolen yarn and a 1/36s worsted yarn as produced by the Pacific yarn tester The relationship between the mean thickness of the yarn and the unevenness, as recorded by the curves, is shown in Fig 10.

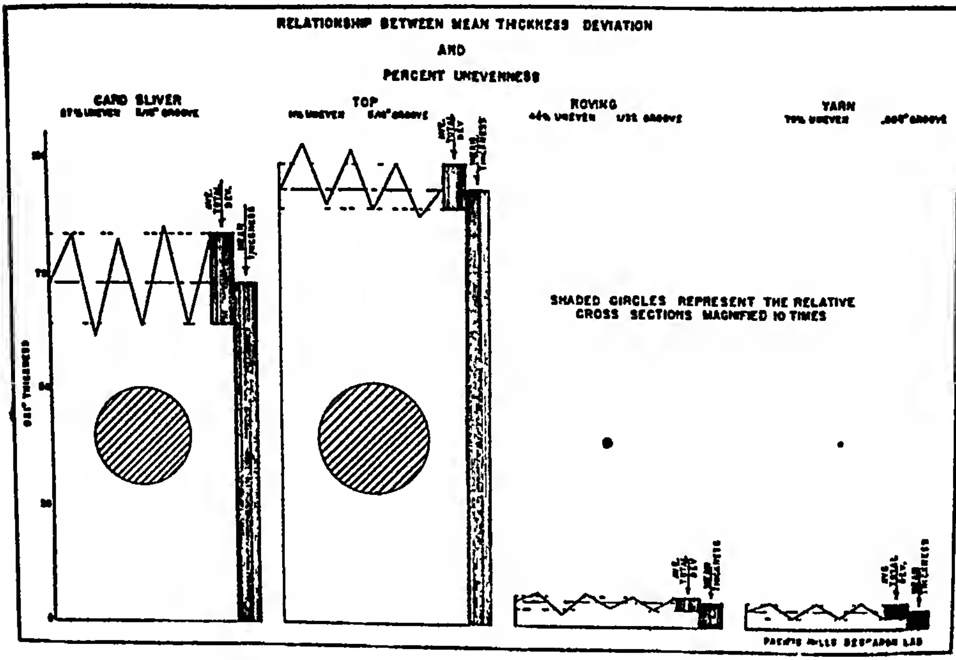


Fig 10

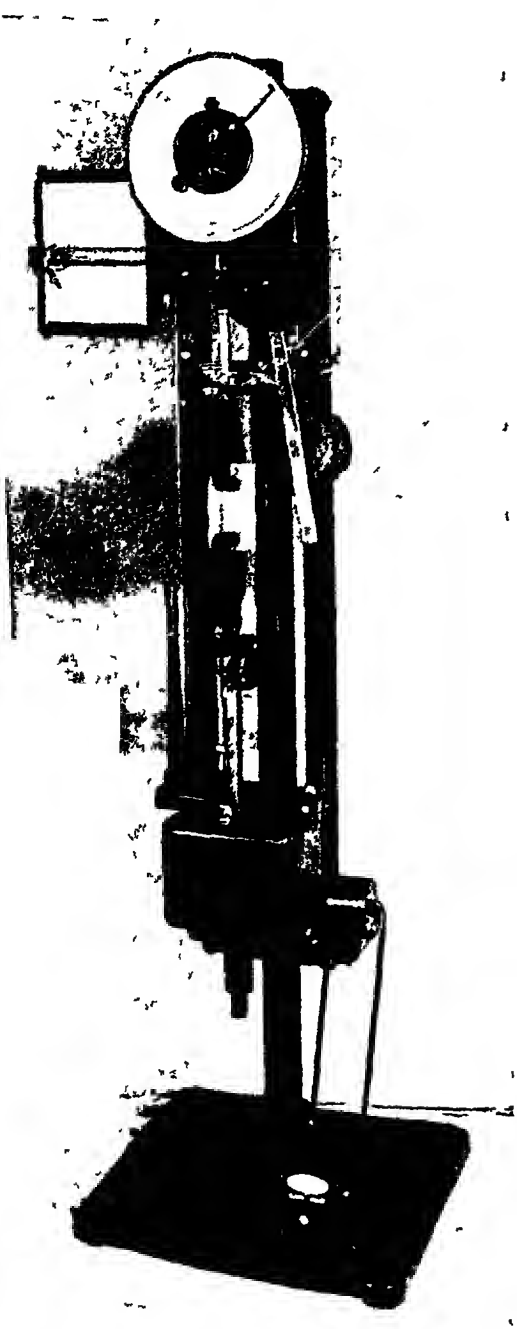
Cloth Testing

Woolen and worsted fabrics are tested for weight, width, weave, construction, breaking strength, abrasion, thickness and warmth The standard testing methods for woven cloth are described in A S T M Designation D 39-39

The *weight* is expressed in ounces per linear yard or it may be converted to ounces per square yard. Five samples, each two inches square, are taken across the width of a piece and the average ounce weight established by weighing on a torsion fabric balance The *width* (distance between selvages) is measured to the nearest half inch

Construction is based on the number of warp and filling yarns per inch This is ascertained by a pick counter For determination of *weave* see Chapter 17

The *breaking strength* and *elongation* are obtained with a breaking strength tester by two common methods, the *grab* and the *strip* method In the grab method a specimen 4 inches wide and 6 inches long is clamped in two jaws 3 inches apart, after which the jaws are moved



apart by motor power until the strip is broken. A machine used for this purpose is illustrated in Fig 11. The strip method consists of ravelling a sample from 1¼ inches down to 1 inch in width after which it is broken as above The strength in pounds and the elongation in per cent can be recorded automatically on a special graph or chart

Abrasion or *wear testing* has not yet been developed to the point where it can be standardized or adequately interpreted Professor Ball[3] stated in a paper before the A S T M. in the fall of 1937

"Much thought, time and expense have been devoted to the subject of wear testing and the development of wear testing machines, in some cases with the hope of finding a method or machine universally applicable To ask the question, 'Can a standard wear test, applicable to all cases, be developed?' is to answer it, for to anyone who has given

[3]Ball, H J Lowell Textile Institute, Lowell, Mass

Fig 11 Breaking strength tester for yarn and cloth (*Courtesy Scott Testers, Inc*)

thought to the conditions producing wear, the negative answer is perfectly obvious The elements of wear affecting carpets, for example, differ so greatly from those affecting a man's suit that it is entirely out of the question to consider a like test for each material Even the fabrics used in the suit itself, the worsted cloth, the rayon lining, the cotton pocketing, are subject to conditions sufficiently different to cast a doubt upon the possibility of a single wear test for them alone Hence it would seem that each condition of wear must become a separate problem in itself, that a test must be devised for each particular set of service conditions to which a fabric is subjected It is along this line that some wear testers have been developed There is one important point to be kept in mind and that is the usual purpose of the tests It is not required that they shall permit the forecasting of the service life of a material in terms of some unit of time Rather the problem is one of comparison, of determining such facts as will warrant an opinion that one fabric probably will or will not last longer than another."

The Army Quartermaster[4] during World War II made extensive tests to study wear and abrasion of fabrics under practical conditions However, as yet no instrument has been designed which correlates laboratory and field tests

One of the most extensively used wear testers is the Wyzenbeek tester Best results are obtained by abrading cloth against cloth Samples are tested in a folded state to simulate the areas at the folds of collars, cuffs, sleeves and pockets of a garment

Thickness The warmth of a fabric is determined primarily by its thickness Thickness measurements are, therefore, of great value in the evaluation of the warmth properties of both apparel and blanket fabrics Measurements of thickness of felts and carpets are of particular importance The compressometer designed by Schiefer[5] offers a convenient and accurate method for measuring fabric thickness

A schematic diagram of the instrument is shown in Fig 12 The specimen, A, is placed upon the anvil, B The foot, C, is circular in shape and varies from one to five inches in diameter It is fastened to the bottom of the spindle, D, of the lower dial micrometer, E The lower surface of the foot is plane and parallel to the upper surface of the anvil The rod, F, is fastened to the top of the spindle at G and to the top of a helical spring, H, at I The bottom of the spring is fastened to the tube, J, at K The upper dial micrometer, L, is fastened to the

[4]Backer, S , *Inter-Society Council for Textile Research,* (Oct 25, 1945), pp 46-54

[5]Schiefer, H F *J Research Nat Bur Standards* 10, (1933), pp 105-713

top of the tube at M The spindle, N, of the upper dial micrometer rests on the top of the rod at O The tube may be moved up or down relative to the frame, P, by turning the knob, Q, of the rack and pinion, R By turning the knob the foot may be lowered upon the specimen The pressure which is applied to the specimen by the foot may be ascertained from the upper dial reading and a calibration curve of the spring The upper dial indicates the elongation of the spring The distance between the face of the foot and the anvil, i e., the thickness of the specimen, is indicated on the lower dial Each dial is graduated to read directly to 0 001 inch

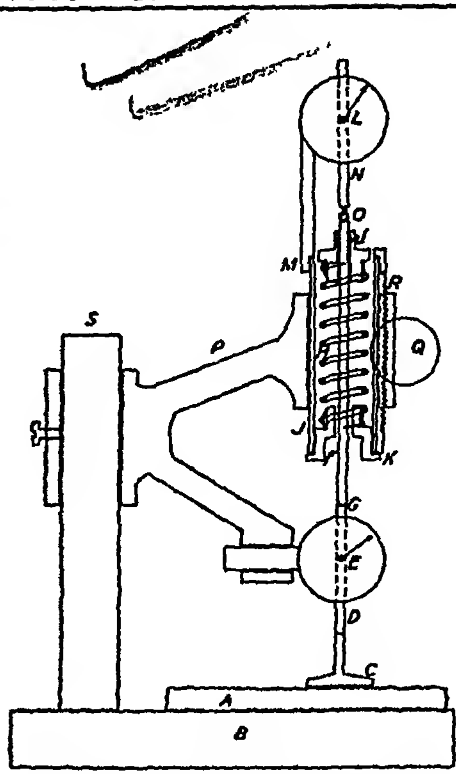


Fig 12 Schematic diagram of Schiefer Compressometer

With this instrument, thickness can be readily determined to 001 inch at pressures ranging from 005 to 3 0 psi As discussed in Chapter 3, it was found that the best correlation between the thickness of apparel fabrics and warmth was obtained when the thickness was determined at a pressure of 005 psi distributed over a 5-inch-diameter pressure foot

Warmth of fabrics There are many factors which enter into the testing of the warmth of woolen and worsted fabrics Because of the extent of winter warfare in present times, warmth of clothing has become of far more vital importance for military forces than in the past During World War II the U S Quartermaster started extensive laboratory studies to establish the specific warmth qualities of each fabric item used by a soldier The numerous reports published, especially the ones from the Harvard Fatigue Laboratory, reveal clearly that the loss of heat from the human body through one or more layers of material to the surrounding air is a very complex process and cannot be duplicated by a simple apparatus and procedure. The simplest phase of the problem is measuring the *heat transmission* through the fabric

or its ability to resist heat transfer. Hence, numerous devices have been devised for this purpose

An improved apparatus for measuring thermal transmission has recently been built by Cleveland at the National Bureau of Standards (Fig 13). This consists of a horizontal plate which is heated electrically and maintained at constant temperature by means of a thermostat

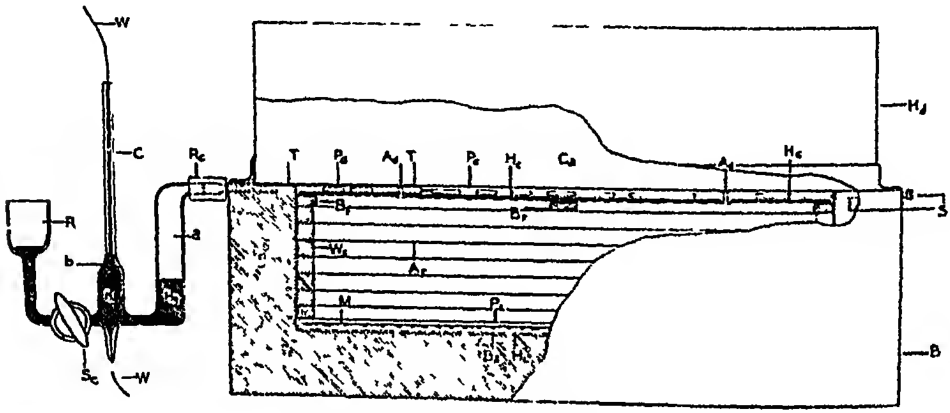


Fig 13 Thermo-transmission apparatus (*Cleveland*)

Surrounding this plate is a guard plate which is maintained at the same temperature to prevent lateral flow of heat into or out of the central plate A second guard heater is placed below the central plate to prevent the downward flow of heat The specimen to be tested is laid flat without tension on the apparatus and enclosed in a copper hood, placed several inches above to eliminate the disturbing influence of air currents of the room Since the thermostatic control results in an intermittent supply of heat to the central heater, an electric recorder is added to the circuit, thus automatically adding the periods during which heat is being supplied The difference in temperature between the central plate and the top of the hood is measured by means of a thermocouple and microammeter The amount of heat supplied to the central heater per unit of time divided by the difference in temperature from the central plate to the hood and by the area of the hot plate is taken as a measurement of the thermal transmission of the specimen

Air permeability The air permeability of woolen and worsted fabrics is not frequently tested A S T M Designation D-737 gives the details of the standard test procedure

Sponging test. The purpose of this test is to determine the relaxation shrinkage still left in worsted and woolen fabrics after finishing Even if a fabric is ready for the needle, this shrinkage may range from zero to as high as 10 per cent in warp as well as filling direction For example, the Army allows a maximum warp shrinkage of 4 per cent for its 18 oz. serge and 6 per cent for the 18 oz elastique The width of the fabric must stay above the minimum specified width of 56 inches The Army test procedure is as follows:

The sample size is a 22-inch length over the full width of the piece The material is laid out without tension on a flat surface, free of wrinkles, in a standard atmosphere for at least one hour After the fabric has come to equilibrium, three distances of 18 inches are marked off in both warp and filling directions The indelible markings must be at least 6 inches apart and one inch away from all edges The piece is sprayed and soaked in cold water until fully saturated and then extracted in a centrifuge The sample is then rolled up and left in this condition for at least five minutes previous to pressing and drying The drying is done on a preheated flat-bed press (Hoffman Press) without steam The sample is laid flat on the bed of the press and as free of wrinkles as possible, then the head of the press is clamped down until the fabric is dry The time in the press may vary from two to eight minutes depending on the type of the press and the weight of the cloth The pressed sample is then laid out flat without tension under standard conditions After one hour of exposure the original 18-inch distances are re-measured and the average changes between the three measurements before and after sponging are calculated in per cent, separately for warp and filling For fabrics ready for the needle the dimensional changes in warp and filling should be less than 2 per cent

Sponging with steam For most ladieswear fabric wet sponging is not suitable Best results are obtained by direct steaming of the sample After proper conditioning, the sample, 22 inches square, marked with 18-inch lines as previously described, is laid on the preheated press and the head is clamped into place Low pressure steam is then applied from the head and the bed simultaneously for 15 seconds The press is then opened and the sample is cooled for 30 seconds by taking it partly off the press and waving it gently This procedure is repeated once more The steamed sample is then laid out under standard conditions and the measurements are taken after one hour

Shrinkage in washing The testing of woolen articles for shrinkage in washing has become quite important with the increased use of wash

able woolens The A A T C C method is based on the use of a washing machine of the cylindrical reversing wash wheel type The sample is run for 15 minutes in a soap solution at 100° F and then rinsed twice for 5 and 10 minutes. The sample is extracted and pressed on a flat press without further drying It is very important that the fabric to be tested first be put through a wet treatment to remove the relaxation shrinkage (see *Sponging*)

The convenient sample size has been found to be a ten-inch square At the start the samples to be tested should be fourteen-inch squares with two-inch cut-outs in each corner The outer edges are then turned under to the point of the incisions and hemmed, forming four tubes around the samples which by now measure about 10 inches square Rods are inserted in these tubes for attaching the pieces to the clamps of the measuring frames The samples are measured under a tension of two pounds applied by the clamps in both warp and filling directions

A woolen fabric or article should be claimed to be washable only when, after five washings following the A A T C C method, the shrinkage does not exceed two per cent

Sock shrinkage The washing procedure used by the British Wool Research Association for socks is as follows

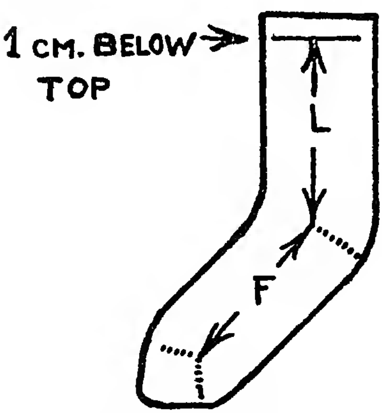


Fig 14 Measuring hose for dimensional change

The socks are measured and then relaxed by soaking in a 0 3% soap solution containing a little alkali (sodium sesquicarbonate, 0 1%) in softened water at 37° C for 1½ hr The distances L and F (Fig. 14) are measured after the socks have been rinsed and laid flat under water Soaking is repeated until no further change in dimensions takes place

Felting shrinkage The socks (air-dry load 150 g), 75 g water and 37 5 g of 5% soap solution are fulled in a Furness fulling machine in which they are given a definite number of blows They are then rinsed and re-measured under water

Chemical Testing

Chemical testing includes the determination of shrinkage of raw wool, fat and oil content, ash content, the presence of sizes, finishing

and other nonfibrous materials, the amounts of acids and alkalies, pH, fiber identification tests for determining wool content in mixtures, and tests for determining chemical damage to wool fibers, yarns and fabrics

Shrinkage of raw wool The accurate determination of the wool content of a lot of raw wool is of great importance to wool manufacturers, wool growers, wool dealers and various Government agencies The official method for sampling and testing raw wool which is used by the Bureau of Customs of the U S Treasury Department is at present the basis for testing imported wool It has been adopted also by the Wool Division of the U S Department of Agriculture and the Wool Associates of the New York Cotton Exchange This method, which was developed by Wollner and Tanner[6] is as follows

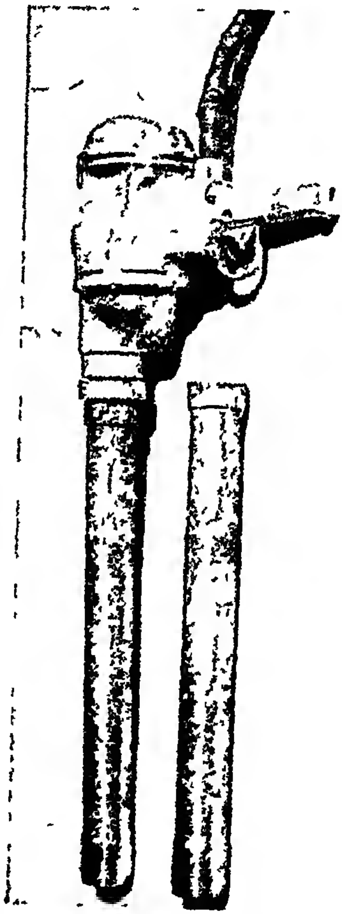


Fig 15 Wool core-boring machine with extra tube

Sampling The sampling procedure involves the use of a simple, electrically motored, core-boring tool which withdraws from the bale a quantity of wool weighing approximately one quarter of a pound The tool is a standard portable electric drill motor, but, in lieu of the usual chuck, it has a bayonet-type driving head to which is affixed an 18-inch stainless-steel tube, two inches in diameter The other end of this tube has provision for holding a removable circular scalloped blade (Fig 15.)

The number of cores taken from a lot of wool, and the depth of penetration are dependent on the statistical and other characteristics of the merchandise In an

[6] Wollner, H J and Tanner, L, *Ind Eng Chem* (*Anal ed*) 13 *pp* 883-887 (Dec 15, 1941) Wollner, H J, *Textile World*, 91 pp 86-87, (Sept 1941)

Fig 16 Sampling Australian wool with a core-boring tool

importation which will run between 100 to 300 bales, a core may be taken from *each* bale In large importation, it is generally not necessary to core every bale unless abnormal conditions require it Where the bales are fewer than 100 in number, the cores are either drilled to a greater depth, or more than one core is drawn per bale (Fig 16)

The cores so drawn are collected in special containers designed to protect them from any change in moisture over extended periods of time. Such samples will weigh from 20 pounds up, of which approximately half will be wool, the balance being impurities

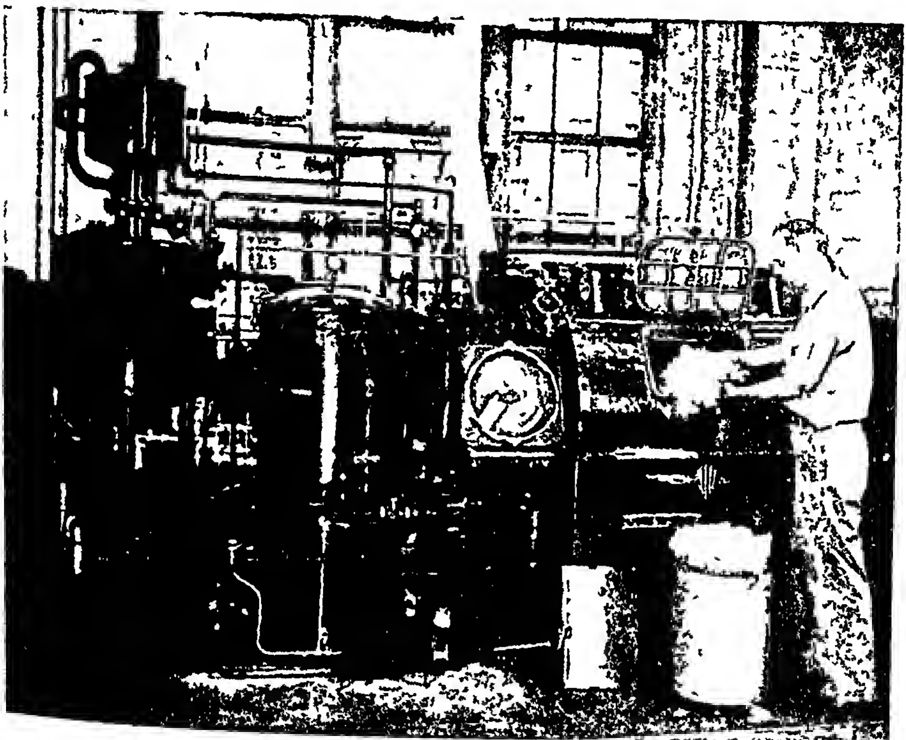


Fig 17 Degreasing wool samples in redesigned dry cleaning machine (*Courtesy U S Treasury Dept, Bureau of Customs Boston Laboratory*)

Scouring In the procedure used by the U S Customs Wool Testing Laboratory, the composite sample is first subjected to a degreasing operation. This operation is conducted in a standard commercial dry-cleaning machine which has been redesigned to prevent any loss of wool fibers, and to handle properly the large quantity of grease and other impurities removed from the wool (Fig 17) The solvent employed is trichlorethylene To expedite the process, all operations are automatically controlled These operations consist of several washings with the solvent, followed by extraction, drying, solvent recovery and deodorizing of the wool

Opening, mixing and dusting The next step is the opening, mixing and dusting of the degreased wool For this purpose a standard 24-inch mixing picker is used along with a continuously operating cone-type duster The wool, as it leaves the duster, is collected in a cage Six test portions of about 100 grams in weight are then taken from the now uniform sample and scoured

The scouring is accomplished by placing the wool in cotton net bags which are then suspended in a warm dilute soap solution, carefully manipulated by hand, and then passed through an electrically operated laundry wringer (Fig 18) This process is repeated in a second soap bath, and the wool is finally rinsed in running water This scouring process completely removes all remaining impurities from most grades of imported wool During this scouring procedure the larger vegetable impurities are removed by hand

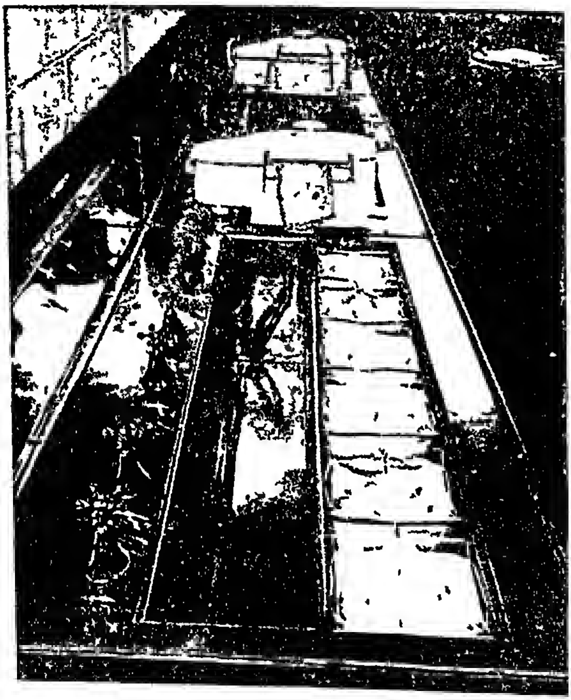


Fig 18 Sample-scouring unit
(*Courtesy U S Treasury Dept, Bureau of Customs Boston Laboratory*)

The samples are then dried and the oven-dry weight established This weight is then corrected to conform to the standard moisture content of 12 per cent.

The wool is further tested and corrected for residual vegetable matter, as well as for its content of ash and extractable material, to determine the clean wool content *Clean wool* is defined as that portion of the wool in the grease or hair which consists exclusively of wool or hair, free of all vegetable and other foreign material, and containing 12 per cent by weight of moisture, 1 5 per cent by weight of alcohol extractable matter and having an

ash content of 0 5 per cent The final result of the analysis is a figure which represents the per cent of the original sample which conforms to the definition of clean wool

The degreasing of the samples prior to the scouring makes the wet treatment considerably easier but is not a necessity in the test procedure. The A S T M standard laboratory method for testing the shrinkage of grease wool (Designation D-584) gives a simplified and cheaper procedure and produces results of the same accuracy

Vegetable matter content Several methods of determining the vegetable matter content of wool are in use. These are the hand picking method, the carbonizing method, the caustic soda method, the peroxide-carbonate method and the comparison method

The *hand picking* method is the most accurate and the most time consuming Because of its slowness the method is not suitable for large scale testing

The *carbonizing* method is based on the commercial method of removing vegetable matter from scoured wools and noils with sulfuric acid. Because of its many manipulations it is difficult to adapt to laboratory-scale testing

The *caustic soda* method is very rapid but inaccurate. In addition to the wool the boiling caustic soda dissolves a variable quantity of lignin and other components in the vegetable matter. The result may be too low by as much as 40 per cent of the actual vegetable matter content

The *peroxide-carbonate* method developed by Lipson[7] is a modification of the caustic soda method The wool is first oxidized by hydrogen peroxide and then dissolved in sodium carbonate

A further improvement in the caustic-soda method was achieved by LeCompte and Coe[8] Their method consists of adding to a 20-gram sample of wool, 400 mls of boiling 10 per cent sodium hydroxide, letting the sample stand for 2 or 3 minutes and then diluting with approximately 500 mls of cold water The vegetable matter is filtered out and washed with 5 per cent sodium hypochlorite Washing with water, drying and weighing follow The method is quick and fairly accurate They report the following percentage of recovery on various types of vegetable matter

[7]Lipson, M *Journal and Proceedings, Royal Society of New South Wales*, LXXVI, 225-228 (1943) *Am Dyestuff Reptr*, 34, pp 250-259 (1945)

[8]Le Compte, G C and Coe, M R, *Am Dyestuff Reptr*, 35, pp 509-510, Nov 4, 1946

TABLE 2 PERCENTAGE RECOVERY OF VEGETABLE MATTER BY THE SODIUM HYDROXIDE ISOLATION PROCEDURE

Type of vegetable matter	*Percentage recovery based on wts of v m. without correcting for ash*
Cockleburs	108-110
Sandbur	105-112
Spiral bur	103-109
Alfalfa	96-104
Straw	84- 89

The results given in Table 2 show a general tendency toward high recoveries of vegetable matter, therefore the authors suggest a correction factor of 0 984.

There is additional value in this method as it takes care of other impurities which are not vegetable matter, such as pieces of skin, taggy portions, and hard pieces of paint

This method is at present a standard method of the Wool Section of the U S Department of Agriculture and is also used by the U. S Customs Laboratory

The *comparison* method developed by Wollner, Tanner and Michelson[9] consists of the immersion of the scoured sample in a liquid of the same refraction index as wool (1 555) resulting in the invisibility or transparency of the wool fibers The vegetable matter embedded in the sample, having a different refractive index or color, remains visible and is compared and matched with photographs of known weights of the same type of materials and in this manner is indirectly weighed

A suitable liquid which duplicates the refractive index of wool is a mixture of monochlornaphthalene and a petroleum distillate

The apparatus required in this method and known as the *Transparizer,* (Fig 19), consists of an immersion vessel with a translucent bottom illuminated from below and a viewing device for the standard photographs In addition, a set of photographic standards (transparencies) representing weighed quantities of different burrs is necessary

The procedure used by the Customs Laboratory is as follows

> Fifty grams of scoured wool consisting of not less than 10 small random portions are taken from the material to be tested The sample is then spread out by hand and dropped into the liquid in the immer-

[9] Wollner, H J, Tanner L, and Michelson, I, *Am Dyestuff Reptr*, 33, pp 375-8, (Aug 28, 1944).

sion vessel in such a manner as to cover the entire bottom of the vessel with an approximately uniform mat. Clumps of vegetable matter in any portion must be dispersed before immersion When the

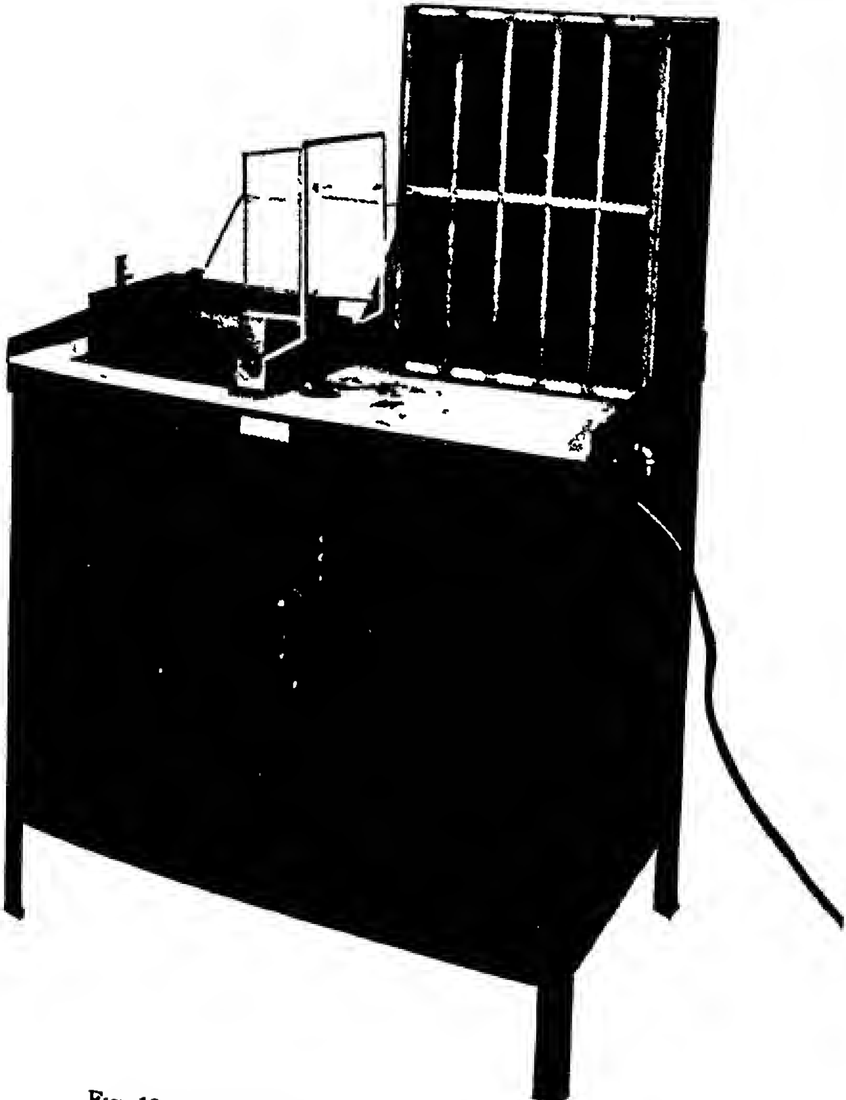


Fig 19 Transparizer for testing burr content of wool
(*Courtesy Baird Associates*)

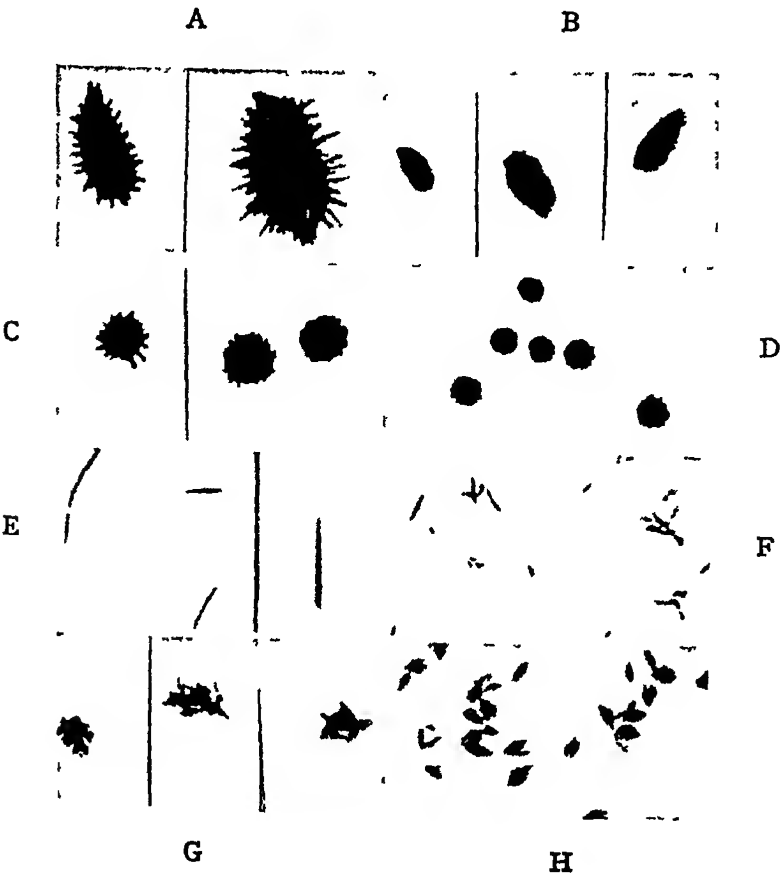
content of vegetable matter in the material is high, it is advisable to make several determinations with smaller samples in order that the vegetable matter may be spread out sufficiently to permit easy matching

Entrapped air bubbles in the immersed wool interfere with the determination To avoid such a condition it is best to drop the wool gently into the liquid previously placed in the vessel, as the wool sinks the air is completely displaced A cover glass is then pressed down over the wool and fastened The layer of compressed wool is generally about ½ inch thick The vegetable matter in the sample is now clearly visible and ready for matching with the standard photographs (Fig 20)

Matching means the reproduction, by means of the standard photographs, of the appearance of the immersed sample as to type, size, and number of particles of vegetable matter Matching is done in steps First, the various types of vegetable matter present are identified by inspection Starting with a particular type, the operator classifies the particles as to size by comparison with the various sizes represented in the several series of standards of the same type, and selects a particular size as the one to be matched Various combinations of plates from the proper series of standards are viewed on the illuminator until one is found which appears to have the same number of particles as the sample After an approximate match has thus been made, the corresponding particles in the sample and on the standard plates are counted and the match is made more exact by such changes in the combination of plates as are required Without removing previously selected combinations from the standards illuminator, the operator repeats these operations for other sizes and types This is done until all the types and sizes present in the sample have been correctly matched by a number of superimposed plates

The total weight of vegetable matter in the sample is the sum of the weights represented by each of the standard plates required in the final match The precision of testing and sampling by this method is shown in Table 3

There are several limitations to the application of this method Difficulties in achieving transparency are encountered in cases where the material has more than one index of refraction or is strongly colored Difficulties in achieving good quantitative determinations are encountered when the number of types of impurities, the number of sizes of each type present, or the total number of particles is large. The most



Top row Cockle or Bathrust bur (*Genus Xanthium*) A—large, B—small
2nd row Common or Trefoil bur (*Genus Medicago*) C—large, D—small
3rd row Shive (*Grass*) E—large, F—small
Bottom row G—sandbur (*Genus Cendrus*) H—barley grass (*Genus Hordeum*)

Fig 20 Common types of vegetable matter found in wool as viewed in the Transparizer (natural size)

TABLE 3 PRECISION OF TESTING AND SAMPLING (IN PERCENT)

Cont veg matter	—Standard deviation, σ— Testing	Sampling	Sampling and Testing
1	0 09	0 11	0 14
4	0 18	0 20	0 27
9	0 45	0 70	0 84

serious difficulty in this method of indirect weighing is encountered in those types of impurities which vary greatly in particle size For spherical particles, an increase in diameter of only 10 per cent corresponds to an increase in volume and weight of 33 per cent, a diameter increase of 30 per cent more than doubles the weight It is, therefore, essential to have standards representing the various sizes commonly encountered within each type of impurity, and to match the sizes carefully

While each type of vegetable matter in wool naturally occurs in a variety of sizes, it is usually found possible to match the common sizes by the use of no more than three series of standards for any one type

Another difficulty is in the variations that occur in the weights of different samples of the same burr type without any outstanding difference in size, as brought out by Lipson

Grease content in scoured wool In checking whether or not a wool has been sufficiently scoured, the most important test is the ether and alcohol extraction The ether removes all of the free fat and small percentages of soap, whereas the alcohol removes soap and waxes The standard method as set up by A S T M is recommended The procedure is as follows

Approximately 10 grams of loose wool are extracted in a Soxhlet apparatus for 20 extractions, which require about 2½ hours The ether is evaporated and the residue dried to constant weight The extracted sample is subjected to an alcohol extraction in a Soxhlet apparatus for 12 extractions with neutral (95 per cent) alcohol requiring about two hours The alcohol is evaporated and the residue dried to constant weight

Some laboratories prefer to use carbon tetrachloride in place of ether because it is less of a fire hazard The carbon tetrachloride extract is always higher, as part of the soap is dissolved with it

A much shorter method has been developed by Mr McKenzie of the American Chemical Paint Company using metal cups with plungers, an aluminim container and a dryer or *greasometer*. It is suitable for mill testing, because it requires only ten minutes to make one test with good accuracy The procedure is as follows

A five gram sample of scoured wool, top or yarn is placed in a metal cup, then 30 cc of carbon tetrachloride is poured on it; the sample is pressed down hard in the cup ten times with a plunger and then allowed to stand for one minute. The pressing is repeated two times at one minute intervals After this, 12 cc. of the solvent are squeezed from the sample into a graduate with the help of the plunger. This liquor is then emptied into an aluminum container and placed in the dryer for the solvent to evaporate which normally takes three minutes The container is removed from the greasometer and allowed to cool off one minute before being weighed By dividing the amount of grease left in the container by 2, each milligram is equal to one tenth of one per cent

Due to the shortness of the method, certain corrections have to be made

If the result is less than 0 30 per cent, add 0 2 per cent

If the result is between 0 30 per cent and 0 50 per cent, add 20 per cent.

If the result is over 0.50 per cent, add 10 per cent

With ten or more aluminum containers and two to three dryers, fifty or more analyses can be made daily without difficulty

Ash content of wool Two or three grams of clean wool are accurately weighed and ignited to constant weight in a porcelain crucible The final weight is recorded as the ash content The normal procedure is to use a Bunsen burner in the beginning and finish up with a blast burner

pH value of wool Ten grams of wool are immersed in 20 ml of water in a 500 cc Erlenmeyer flask After soaking 20 minutes at room temperature the pH value can be determined by colorimetric or electrometric methods.

Oil and size content in yarns Yarns are generally tested for oil and size content Determination of oil content is done by ether and alcohol extraction, described in A S T M Designations D 403 and 404 and is listed as extractable matter. The method used for sizing compounds present in sized warps is described in A S T M Designation D 629-46T. The oven-dry sample is immersed in a 3 to 5 per cent aqueous solution of a starch and protein-solubilizing enzyme preparation for one hour at the optimum temperature range for the particular enzyme used The sample is then rinsed twelve times in hot distilled water and dried The loss in weight represents the amount of size

Chemical tests on fabrics Fabrics are generally tested chemically for fatty matter, sizing compounds, finishing and other materials, amount of acid and alkali (or pH value), fiber content and color fastness

Tests for *fatty matter* are based on the Soxhlet extraction for control purposes in manufacturing Sizing compound tests are the same as for yarns For identification of finishing compounds the use of the A A T C C. procedures are recommended

The *acid* or *alkaline* condition of the cloth is determined by its pH value by a process similar to that described for loose wool. Fabrics should be cut into small pieces before immersing in the test solution for one hour before the first readings are made.

For quantitative analysis of the amount of *acid* present in pieces, the modified pyridine method is recommended A two-gram sample is placed in an Erlenmeyer flask (500 cc) and 200 cc of water and one cc of pyridine are added The flask is then stoppered and allowed to remain for two hours with occasional shaking The liquor in the flask is then transferred to another flask and the piece rinsed three times with 100 cc of fresh distilled water, all three rinse waters being added to the original extracted liquor The total solution (500 cc) is then titrated with N/10 sodium hydroxide, using phenolphthalein as an indicator This method gives excellent results for control work in the carbonizing process and also for piece-dyed materials

For quantitative analysis of the *alkali* present in pieces, the only method for which reasonable accuracy can be claimed is the one by Hirst and King [10] By this method the wool is placed in water containing terephthalic acid in suspension The alkali in the piece reacts with the acid to form sodium terephthalate, which is soluble in water. The amount of salt formed is estimated gravimetrically by filtering out the unchanged terephthalic acid To the filtrate is added dilute sulfuric acid, which converts the sodium terephthalate into insoluble terephthalic acid, which precipitates and can be filtered off and weighed This method is used for dyed fabrics which bleed For white fabrics, loose wool or yarn, the alkali is determined directly by volumetric means, using Bromophenol Blue as an indicator The liquid containing terephthalic acid and sodium terephthalate remains purple until the whole of the salt is converted into acid, using dilute sulfuric acid as a converter

Recommended also is a modified form of the pyridine method as used for the acid determination A two-gram sample is treated for two hours with an excess of normal sulfuric acid (10 cc) in 250 cc distilled water The solution is then poured off and the piece allowed to remain in the beaker until nearly dry From then on the procedure is the same as for the determination of acid in the piece The acid left in the solution and the acid absorbed by the piece, which is found by the titration with

[10] Journal of the Textile Institute, 17, (1926), pp 94-100

N/10 caustic soda, is subtracted from the total acid added The difference is the amount of acid needed to neutralize the alkali in the piece

Fiber content For the determination of the fiber content in fabrics by chemical analysis, the quantitative methods described in A S T.M Designation D 629-46T and by the A.A T.C C in the tentative test method *Identification and Quantitative Separation of Fibers* are recommended. The most important method for the determination of wool content in wool-cotton, wool-rayon and vegetable fiber mixtures, is the *sulfuric acid method* developed by the A A.T C C. The procedure is as follows.

A Standard procedure Clean, dry and weigh the sample (about 2 grms), immerse in 200 ml of a boiling 1% solution of sulfuric acid for about 7 to 10 min , transfer to a Gooch filter and remove the excess acid by suction Place the sample in 200 ml of a 70% solution (by weight) of sulfuric acid at 100° F (38° C) and work it for 15 min Filter on a Gooch or fritted glass filter (or 100-mesh screen) and wash well with cold water, then place the sample in a beaker of 2% sodium bicarbonate at room temperature for 5 min Filter again, wash well on the filter, dry and weigh This method dissolves all the ordinary fibers except wool which is left as a residue, no correction factor is necessary for a normal wool

If reprocessed and/or reused wools are claimed or known to be present, the sulphuric acid residue should be adjusted by adding to it an amount equal to the product of the sum of the percentages of reprocessed and reused wools times 0 04 For example, if it is claimed or known that a product contains 30 per cent of reprocessed and/or reused wool and a woolen fiber content of 78 7 per cent is obtained by analysis by this method, then there should be added to the percentage an amount equal to 30 times 0 04 or 1 2 per cent, making the total wool content 79 9 per cent

B. Alternate sulfuric acid method particularly adaptable to routine analysis The dried, weighed sample (2g) is immersed in 200 ml. of a boiling 1% solution of sulfuric acid for 7-10 mins It is then transferred to a Buchner or Hirsch funnel (45 mm dia disc) and the excess acid solution removed by suction The sample is allowed to cool, then it is held over a 400 ml beaker and carefully cut into strips or shreds approximately ⅛" x 1". 200 ml of 70% ± 1% sulfuric acid solution at 100° F are added and the whole allowed to stand 15 mins with frequent stirring. In the meanwhile a liter beaker is partly filled with 600 ml of cold water and at the expiration of the 15 mins the 70% acid solution con-

taining the sample is cautiously but quickly poured into it. The 400 ml. beaker is rinsed with 2 50-ml portions of water. The sample is then recovered by filtering the above solution in the Buchner or Hirsch funnel through a disc of bleached, unstarched 80/80 cotton print cloth using suction The sample is rinsed with several portions of cold water, sucked reasonably dry and the whole pad (disc plus fiber) carefully lifted out of the funnel by means of tweezers and dropped into 20 ml of a cold 2% solution of sodium bicarbonate and neutralized for 5 mins It is again collected on the same fiber disc in the funnel, rinsed with several portions of cold water, sucked reasonably dry, the disc lifted and placed in the oven to dry When dry the recovered fiber mass is carefully transferred to a weighing bottle, placed in the drying oven again and dried to constant weight Results should be calculated on an oven dry basis

Wool damage One of the most common problems in wool manufacture is determination of the damage done to the wool fiber during processing This, in turn, leads to the cause of the damage, and the remedy, if possible The most common types of damage are those due to alkalis, acids and oxidation

Chemical methods for measuring the amount of damage which fibers or fabrics have undergone during manufacturing or wear are based on the greater sensitivity of damaged fibers to chemical treatments and their increased absorption value for certain dyes Most of the tests are not specifically for one particular type of damage In all cases, it is found that the wool keratin in the damaged fiber has been changed chemically, as can be detected by the change in the sulfur, cystine and nitrogen contents. The determination of sulfur and other keratin compounds is too involved for general laboratory use The colorimetric methods are the simplest, but also have a disadvantage in that they can be used only on undyed material The two best known are the *methylene blue absorption* by Kronacher and Lodemann and the *benzo-purpurin* tests of Sieber The procedure for the benzo-purpurin is as follows

One gram of neutral wool is placed in 100 cc of a solution (0 1 grams per liter) of Benzo-purpurin 4B (duPont) The solution is brought to a boil and boiled for one minute The material is then washed in hot water until all the excess dye is removed, and dried

After this treatment, undamaged wool shows only a slight pink color, whereas damaged wool may range in color from a pink to a dark red,

Another method is the Kettering modification of the Rimington-Pauly test[11] which is more or less a quantitative method. The procedure is as follows.

> To a mixture of 10 cc of 10% sodium sulfanilate and 5 cc. of 8% sodium nitrite, add 2 cc. of conc. hydrochloric acid, shake gently, and let stand for one minute Then add to this a mixture of 15 cc. of 9% sodium carbonate solution which contains a 0 1 gm. sample weighed under standard conditions. Allow to stand exactly 10 min Remove the sample, wash it in a sintered-glass crucible with 300 cc of distilled water, and dry it on a watch glass in a dark room When dry, add the sample to 50 cc. of 2N sodium hydroxide and allow to stand for 18 hrs. Shake well and compare this solution with 0.1% New Acid Brown S, using a colorimeter and artificial light. (Prepare the dye solution the day before and filter immediately before use) For the purpose of establishing a scale, Rimington defined 100 units of damage to be such that a 0 1 gm sample, after treatment, yielded 25 cc of solution with exactly the same color intensity as the 0 1% New Acid Brown S. All reactions have to be performed under a constant temperature of 70° F. ±1° and every solution must be freshly prepared

Acid damaged wool is best detected by combined chemical and optical methods requiring the aid of the microscope since no purely chemical methods are available.

The best method for determining the extent of oxidation in wool was developed by Harris and Smith[12] The basis of this method is the fact that wool, when attacked by oxidizing agents, shows as increased solubility in alkaline solutions The procedure is as follows

> One gram of wool is treated with 100 cc 0 1 N solution of sodium hydroxide at 65° C for one hour After this treatment the wool is recovered on a Buchner funnel, washed with about 2 l of water and dried to constant weight at 105° C

The loss in weight is an indication of the damage The alkaline solubility of undamaged wool does not normally exceed 12 per cent As soon as the alkaline solubility is higher than 20 per cent, the wool is considered severely damaged The alkali solubility test is applicable for oxidation damage caused by (1) hydrogen peroxide bleaching, (2) chlorination and bromination, (3) exposure to light

In any oxidation of wool, sulfur compounds are set free These com-

[11] *Journal of Home Economics*, 28, No 4 (1936) pp 255-9

[12] Harris, M , and Smith, A L , *J Research, Nat Bur Standards*, 17, RP 928 (Oct 1936)

pounds react with heavy metals such as tin and lead to form the brown and black metal sulfides On this reaction Smith and Harris have based the lead acetate test and Becke, the tin-salt test.[13]

Color Fastness

For determining the fastness of dyestuffs on the fiber, use of the standard test methods of the American Association of Textile Chemists and Colorists as published in their yearbooks is recommended The methods of special interest to wool men are:

Fastness to Light, Laundering and Domestic Washing W-1; Scouring and Mill Washing W-2, Fulling W-3; Carbonizing, Perspiration, Acids and Alkalies, Sea water, Rubbing (Crocking) and Drycleaning

Whenever possible in woolen mills the tests should be conducted under actual process conditions

The following apparatus are used for some of the above tests. *Light test* Sun exposure cabinet Such a cabinet, generally made from wood, is covered with a good grade of window glass approximately 1/8 inch thick and open at the sides to allow free access of air to all specimens. The specimens are placed at a distance from the glass of not less than 1/2 inch The cabinet is mounted on a roof so that the specimens are inclined due south at an angle of 45° from the horizontal. Exposures are made between the hours of 9 A M and 3 P.M. (standard time). For proper classification of the light fastness it is necessary that the samples tested be exposed simultaneously with standard dyeings. Seven such standard dyeings are available from the A A T C C.[14]

Artificial light test The preferred apparatus for this test is a Fade-Ometer, type FDA—R In this apparatus, tests specimens measuring 2 1/2 by 3 inches are exposed to a carbon-arc light, around which they rotate slowly The air around the samples during exposure is humidified and the temperature automatically controlled so that it does not exceed 105° F As these lamps vary considerably in their fading action it is essential that a control dyeing be exposed for each 20-hour cycle that the machine is used It is essential that the Pyrex glass cover which encloses the carbon arc be cleaned every 20 hours to assure uniformity of fading Another limitation is that some dyes fade differently in this lamp than they do under the standard sun test.

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[13] *Lehnes Faebr Z*, 3, Mch 1912

[14] Chairman, Research Committee, American Association of Textile Chemists and Colorists, Lowell Textile Institute, Lowell, Mass

Washing, laundering and fulling. The standard machine adopted by the A A.T C C is the Launder-Ometer It consists of a heavily constructed copper tank, supported upon a rigid angle-iron frame. Within this tank there is a brass and aluminum rotor that carries up to twenty standard pint jars in which the tests are made. The speed rotor is securely fastened to a polished stainless steel shaft, which is rotated in double annular ball bearings The rotor is driven at a standard speed of 42 rpm by a one-quarter h p motor, controlled by a clutch of the double slotted type A round, rimmed handwheel securely mounted on the shaft enables the operator to turn over the rotor for inspection or loading.

Rubber or metal balls are added, as specified, to the jars along with the material being tested to increase the intensity of the action, cut down the time element, and more nearly duplicate the actual conditions of laundry and scouring practice The tank is regularly heated by a gas burner, but may be heated electrically or by steam The apparatus is very useful, also, for determining the scourability of wool lubricants such as mineral oil emulsions For fulling tests in the Launder-Ometer a knitted tubing is used

Crocking. The official machine of the A A T C C is the Crockmeter, obtainable from the Secretary of the Association The crock spot, which is produced on a white cloth by sliding it back and forth twenty times over the test specimen, is evaluated by comparison with the A A T.C C Color Transference Evaluation Charts

Optical Methods

In this section all methods are discussed in which the use of a microscope is essential The most important optical methods established in the woolen industry are the methods of test for fiber identification, fineness of wool, and fiber damage

Microscopy. Microscopy requires a delicate technique and considerable skill on the part of the technician, and this is particularly true in the case of fiber microscopy A knowledge of the proper methods of preparing specimens for examination, of mounting them and of the proper selection of lenses, is essential The characteristic markings and structure of the various fibers can only be brought out by careful techniques These can only be developed with considerable practice and an intimate knowledge of the possibilities of the microscope

Fiber specimens may be mounted in various ways For temporary

mounts and rapid observance an ordinary water mount may be used. Water has the disadvantage that all fibers swell in this medium; for example, the wool fibers swell 10 per cent and rayon fibers as much as 30 per cent The best mounting agent for general work is C.P. glycerine No swelling occurs and any mount made with glycerine can be used for measuring purposes

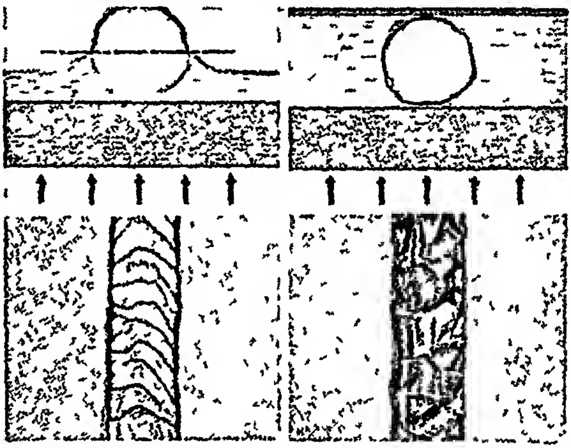
For the longitudinal observation of the fibers, always the first step in microscopic fiber analysis, the fibers should be well separated so that as few as possible cross one another. If necessary, they should be cut in short lengths to come within the area of the cover glass The common method is to put two drops of glycerine in the middle of a glass slide with a dropper or glass rod and spread them over approximately half the area of a cover glass Then, a small bundle of fibers is laid neatly on top of the glycerine and, with the help of a dissecting needle, slightly immersed in the liquid With a tweezer the cover glass is carefully laid over them, the air allowed to escape and then the glass is gently pressed down to flatten the specimen. In making observations under high power it is especially necessary that the fibers lay individually, if several are piled up across one another the focus becomes distorted and, unless the observer is skilled, he may mistake shadows for important markings In most instances, the characteristic markings, both on the surface and in the interior of the fibers, are clearly enough defined for the identification of fibers such as wool, silk, cotton and some of the rayons In case of undyed fiber it is often necessary to color the fiber slightly to bring out the markings A favorite stain for wool fibers is Safranine

Apparatus The various optical concerns have developed special instruments for microscopic observation of fibers, yarns and fabrics For the observation of fabrics and yarns, a wide field microscope is very useful This instrument has a drum-type rotating objective holder which permits instantaneous change of magnification It has six different magnifications ranging from 7 to 30 times and gives a three-dimensional enlarged view

For higher magnifications and observation of single fibers, various types of standard microscopes are available, having magnifications ranging from 50 to 500 or more For textile fibers the best magnification ranges are between 250 and 500.

Methods for fiber identification For proper identification of the fibers it is necessary to study the structure of the fiber itself, i e, its physical elements, the *epidermis, cortex* and *medulla*. A special study of the epidermis structure is necessary in wool and mohair blends, which are closely related animal fibers and can only be distinguished

by the difference in the scale formation. In glycerine, as in most of the other mediums, the visibility of the scale lines is very poor and therefore, the counting or measurement of the scale lengths is very tedious and time consuming Various methods have therefore been developed The best known method was developed by Manby and Hardy and further improved by Reumuth, and lately by Schramed and Helm The basis of this method is that the fiber is only half immersed in the imbedding medium, with the result that the lower part of the fiber is optically eliminated, and the surface structure is brought out clearly (Fig 21) The procedure is as follows: The fibers are fixed across a glass or metal frame The frame, with a dozen or more single fibers, is then laid across a glass side prepared with a fine coating of an imbedding medium such as diluted Canada balsam, celluloid in amyl acetate, or any good quality of colorless finger-nail polish Care must be taken that the fibers are only partly immersed in the medium As soon as the solvents have evaporated and the coating is dry the fibers are trimmed carefully from both ends of the frame



New Way Regular Way
Fig 21 Embedding methods for surface structure study *Reumuth*

Another method which gives the same result is preparation of a cast or imprint of the fiber surface The method described above can be followed but, instead of leaving the fibers half immersed in the imbedding medium, they are removed and the mold which is left can be photographed This method can be considerably simplified by the use of transparent thermoplastic films as described by Hardy and Plitt[15]

To study the *cortical cells* the fiber has to be gradually disintegrated The best known methods for this purpose are the use of concentrated sulfuric acid, formic acid and ammonia McMurtrie[16] gives the follow-

[15]Wildlife Circular 7, U S Department of Interior, (1940).
[16]McMurtrie, W , *Report Upon an Examination of Wools and Other Animal Fibers*, U S Govt Printing Office (1886)

ing procedure. The fibers are placed on a glass slide and covered with the cover glass, which is held in position by a small drop of water One or two drops of concentrated sulfuric acid are then applied near the edge of the cover glass so they will spread and be drawn under it by capillary attraction The fiber will disintegrate down to a mass of elongated fiber cells This breakdown is speeded up by application of heat and pressure In recent years most of the studies on cortical cells have been made on cells liberated by bacterial action Burgess[17] suggests the following technique

(a) Trypsin solution

Trypsin (B D.H)	0 5 g.
Water (distilled)	100 cc

(b) Buffer solution (pH value 8 6)

0 10 M Potassium di-hydrogen phosphate . .	34 cc
0 05 M Borax	66 cc

The wool (0 1 g) is relieved of natural or added grease, wetted out in water, and immersed in a mixture of 5 cc each of solutions (a) and (b) in a test tube Two drops of toluol are added and the tube corked and incubated at 35° to 40°C Full disintegration is usually accomplished within 48 hours

Cross sections To study the *ovality* or *contour* of a fiber the preparation of a cross section is essential and only a thin cross section can give all the information In case of strong pigmented and dark-dyed fibers the longitudinal view is of little value and the cross section has to give the information desired The various rayons can be identified properly only by the shape of their cross section These typical cases illustrate clearly the necessity of good cross section methods

The simplest laboratory method of making thin cross sections of fibers was developed by Hardy [18] His device is a simplified and very compact microtone (Fig 22) With his technique, sections of fibers suitable for microscopic examination may be prepared in a minimum length of time

The complete instrument measures 3⅛ by 11/16 inches and consists, essentially, of two separable plates, A and B, each 3/64 inch thick, the plates are frictionally held in proper relation by slide joint C The plate B has a milled, smooth-walled fiber-receiving slot D, 0 0085 inch wide and ⅜ inch long The companion plate A carries a tongue, which enters the slot D longitudinally as shown, and fits into it within very close

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[17] Burgess, R, *J Textile Inst*, 20, pp 333-372 (1929)

[18] Hardy, J I, *A Practical Laboratory Method for Making Thin Cross-section of Fibers*, U S D A Circ No 378, Nov 1935

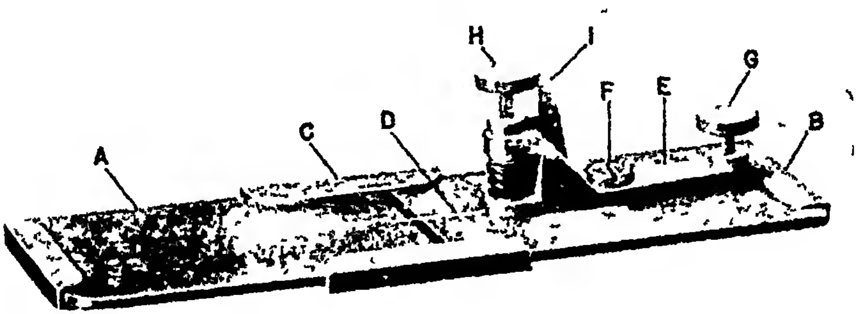

FIG 22 Hardy's thin cross section device (*Courtesy A M de LaRue*)

limits. This tongue is supported by a web which lies beneath the plates and is not visible in the illustration Mounted on plate B is a swiveling bracket E pivoting at F, and held in proper relation to the slot by means of a pin-lock G The bracket carries a micrometer screw bearing a graduated head H readable by reference to an index I This micrometer screw actuates an extruding plunger (not visible) which may be made to enter the slot perpendicularly by turning the milled screw H

In use the two plates A and B are separated, the lock G released, and the swivel E turned to a position transverse to the plate B. The fibers to be examined are packed into the slot D and compressed into a compact bundle by inserting the tongue and pushing the two plates A and B into engagement The excess material extending from either side of the plate is trimmed off flush by means of a suitable cutter, such as a safety razor blade. The bracket E is now turned to the position shown in the illustration and locked, the screw head H being turned until the plunger is in full abutment with the bundle of fibers, indicated by a slight extrusion of the fibers observable on the reverse side of the plate A drop of collodion is put on the end of the bundle of fibers exposed opposite the plunger, allowed to dry, and the slightly projecting end is sliced off and discarded The graduated micrometer screw is now turned according to the thickness of the section desired, the solution again applied, allowed to dry and the section sliced off This slice is suitable for mounting with Canada balsam under a cover glass for microscopic examination As many sections are made as are required The minimum thickness obtainable is of the order of 0 0001 of an inch The actual time consumed in the complete operation is about ten minutes, for an experienced operator, as compared with several hours using the former technique

More rugged instruments are built on the same principle to make the short fiber sections used in the determination of fiber fineness (Fig 23.)

The device has many practical applications Information on the commonly used wool-rayon, and wool-cotton-rayon mixtures can be supplied quickly and quantitatively through the use of this device Also blends of animal fibers such as wool-alpaca, wool-camel hair, wool-rabbit hair and similar blends may be determined quantitatively The device is especially valuable in detecting questionable or fraudulent practices or misrepresentation of quality The following examples illustrate the procedures found in A S T M Designation D 629 for the quantitative determination of fiber mixtures:

Fig. 23 Cross section device for making short fiber sections for fineness measurements (*Courtesy A. M de LaRue*)

Alpaca-wool mixture. Through a fine cross section the numerical percentage of wool and alpaca fiber was found to be 30% alpaca and 70% wool The width of the wool fiber was found to be 22 microns and the alpaca 27 microns The weight percentage was found by multiplying the number of fibers by the square of the average diameter and by the specific gravity (Table 4.)

TABLE 4 QUANTITATIVE DETERMINATION OF CONTENT OF MIXTURES BY NUMBER, DIAMETER AND SPECIFIC GRAVITY OF FIBERS (IN PERCENT)

	Alpaca-wool mixture		*Rayon-wool mixture*	
	Alpaca	*Wool*	*Rayon*	*Wool*
Number of Fibers N	30	70	68	32
Diameter of fibers D	27 0	22	22	26
Specific gravity S	1.30	1 30	1.53	1 30
$N \times D^2 \times S$	28431	44044	50355	28122
Percentage fibers in sample	39	61	64	36

Wool-rayon mixture. By longitudinal observation and cross section the numerical percentage was found to be 68% viscose rayon and 32% wool. The width of the wool was 26 microns and the rayon was 5 denier (equal to 22 microns) (Table 4 Fig 24 shows a similar blend)

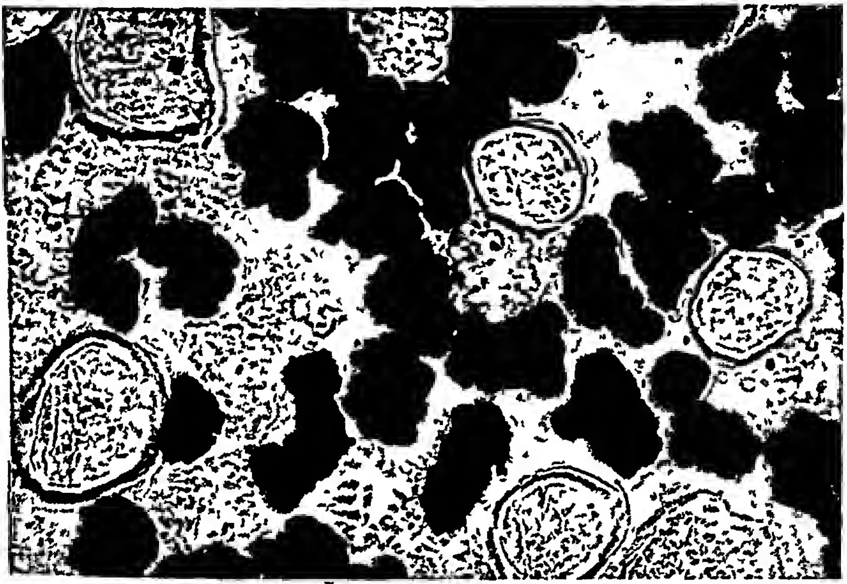

Fig 24 Wool-rayon mixture cross section (X 500)
1/3—58s wool (white), 1/3—5 den lustrous viscose (white), 1/3—5 den viscose (black)

Standard Methods of Tests for Fineness of Wool

Standard test methods have been developed jointly by the members of Section 1, Wool Sub-Committee A3 of Committee D 13, A S T M and the members of the Wool Top Committee of the National Association of Wool Manufacturers based on work done by Hardy, Kruegel, Lauth and von Bergen [19] These methods are described in detail in A S T M Designation D-419 *Standard Method of Test for Fineness of Wool* and also in Designation D-472 *Specification and Method of*

[19] *Textile Fiber Atlas* (2nd ed , New York Textile Book Publishers, 1945)

Tests for Fineness of Wool Tops which is also the official method of the United States Department of Agriculture There are two methods, i e , the width method and the cross-section method.

Width method. The A S T M Specification states that "The width method is based on the projection of the image of the fiber at a high magnification through a microscope on to a wedge ruler. The width of the image of the fiber is recorded on the wedge ruler by which the fibers are automatically sorted according to their width."

Two methods are used to prepare the test specimen, the *long fiber* method and the *short fiber* method. In the long fiber method the test specimen, containing about 120 fibers is prepared in the following manner.

> From a staple, carded sample, or top a strand of fibers approximately one-eighth inch in diameter and two inches or more in length is separated A small section half an inch or less in length is cut from this strand with a pair of scissors A drop of glycerine is placed on a glass slide and the fiber bundle mounted The fibers are uniformly spread with the aid of dissecting needles and covered with a cover glass

In the short fiber method the fibers are cut to approximately 150 microns in length This is about 1/170 of one inch A cross section device is necessary to prepare such short lengths The sample preferably should be in the sliver form The cross sectioning device should be capable of holding a top sliver of the usual thickness The sample is locked in the slot of the holder and the projecting fibers trimmed flush with the upper and lower surfaces of the holder plate. Using the ejector mechanism the fiber bundle is extruded to the extent of about 150 microns The projecting fibers are moistened with a drop of mineral oil, and allowed a few seconds for penetration before cutting the fibers off with a razor blade The fiber sections are then transferred to a glass slide, and dispersed in 2 or 3 drops of oil The slide is completed with the cover glass (Fig 23)

The short fiber method, even though it involves more difficulty in preparing the specimen and depends on the use of a cross sectioning device, insures a much better average sample and the short fibers can be measured at a higher speed and with better accuracy

The slide, prepared in either way, is then placed on the mechanical stage of the microscope and the measurements begun either from the left or right edge of the cover glass The image of each fiber is brought into sharp focus on the wedge ruler. The wedge ruler is turned until the image of the fiber to be measured is projected directly between the

two lines of the wedge. The place where the wedge has exactly the same width as the image of the fiber is marked with a pencil line on the wedge ruler. (Fig 25.)

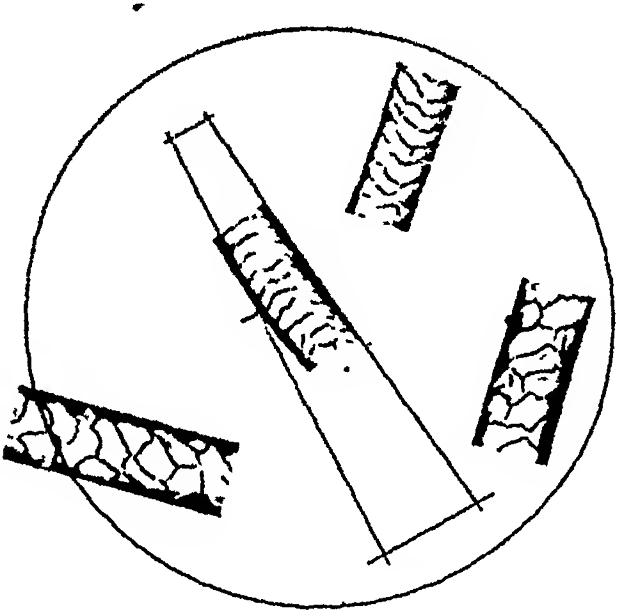

Fig 25 Wool fibers measured by the wedge ruler

The image of the next fiber is brought into focus and measured as directed above and the measurements repeated on successive fibers until 100 fibers have been measured. For each 100 fibers a new wedge ruler is used. The procedure is repeated on additional test specimens until the number of fibers are large enough for proper calculation of the average From the wedge ruler measurements the average fineness of all fibers measured can be calculated To insure accuracy in these measurements the Standard Wedge Ruler, obtainable from the United States Department of Agriculture (Wool Section), should be used

The wedge ruler has certain shortcomings which lower the precision and take time to overcome A measuring device known as the Spirascale was designed by Wollner, Tanner and Spiegel[20] to offset the shortcom-

[20]Wollner, H J, Tanner, L, and Spiegel, H H, *Amer Dyestuff Reptr*, 33, (July 17, 1944), 307-8, 321-322

ings of the wedge ruler. The certainty, speed and precision with which exact tangency is achieved with this device unquestionably would be superior to those attainable by the use of the wedge ruler Unfortunately the device in its original form has proven unsatisfactory as it did not stand up under daily use

Cross section method. In this method the image of the fiber cross section is projected through a microscope and measured as described under the width method or preferably recorded on sensitized or photostatic paper The fiber images are measured in two directions at right angles to each other, by means of a celluloid wedge measure or by means of a bi-diameter scale Grandstaff and Hodde[21] described an improved bi-diameter scale (Fig 26) which allows for more rapid measuring of individual fiber cross sections

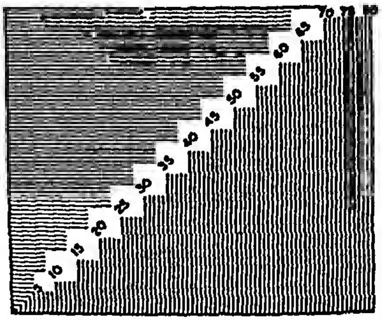

Fig 26 Bidiameter scale for measuring individual fiber diameters.

The specimen is mounted in a cross section device which consists of two parts a fiber holder with a fiber slot and a slide-holder with a metal plunger to fit into the slot of the fiber holder The test specimen consists of a strand of several thousand fibers, which is inserted into the slot of the fiber holder and then pushed with the aid of a metal plunger into the fiber slot until all the fibers are held securely in place The slide of the slide-holder should exert sufficient tension on the fibers to hold them without distorting their shape. Protruding fibers on both sides of the metal slides are cut off and a drop of celluloid solution (collodion) is applied and allowed to dry The fibers are then cut off flush on both sides of the fiber holder by means of a sharp razor blade. When the fibers are smoothly cut the cross section device is placed on the stage of the microscope and the image of the cross section of the specimen is focused upon a sheet of white paper For photographic purposes it is advisable to use an orange color filter to bring out greater detail on the photostatic paper Both methods find a wide application in the trade

Short cut cross section methods. For sheepbreeding work, such as selecting sheep on the merit of their fleeces or culling individual sheep producing undesirable wool from a flock, Hardy and Wolf found the

[21] Grandstaff, J O and Hodde, W L Circular No 590 USDA Dec. 1940

standard cross section method too slow They developed two new methods for rapid determination of fineness and cross sectional variability of wool These are known as the *count* and *comparator* methods [22]

In the count method the mean diameter of a given number of fibers is estimated by ascertaining the number of fibers in an area of 125 square centimeters of the projected image at a magnification of 500 diameters. By use of curves the mean diameter of the fibers can be determined directly, depending on the tightness of the packing, whether loose, adjacent or solid The last two types of packing are expressed by formulas obtained by mathematical analysis Table 5 shows the relationship between the number of fibers and average diameter of fibers, from the finest to the coarsest, for the three types of packing

TABLE 5 RELATION BETWEEN THE MEAN DIAMETER AND THE NUMBER OF FIBERS IN AN AREA OF 125 SQUARE CENTIMETERS FOUND ON THE PROJECTED IMAGE OF THE CROSS SECTION AT 500 DIAMETERS[1]

Mean diameter of fiber (microns)	*Fibers counted in 125 square centimeters of area packed* — *Loose*	*Adjacent*	*Solid*	*Mean diameter of fiber (microns)*	*Fibers counted in 125 square centimeters of area packed* — *Loose*	*Adjacent*	*Solid*	*Mean diameter of fiber (microns)*	*Fibers counted in 125 square centimeters of area packed* — *Loose*	*Adjacent*	*Solid*
	Number	*Number*	*Number*		*Number*	*Number*	*Number*		*Number*	*Number*	*Number*
10		500	637	25	74	80	102	35	36	41	52
15		222	284	28	57	64	81	37	32	37	47
18		154	197	30	48	56	71	39	28	33	42
20	122	125	159	32	42	49	62	40		31	40
22	98	104	132	33	40	46	59	42		28	36

To obtain the fiber variability the two largest and the two smallest fibers in the cross section are measured directly. The differences between the average of the two largest fibers and the average of the two smallest fibers is used to represent the range A set of empirical curves (Fig 27) with variables of mean diameter, standard deviation, and coefficient of dispersion, is used to estimate the standard deviation By the count method it is claimed that the average diameter of wool samples can be estimated within ±0 5 microns of the value obtained by individual measurement of 100 cross sections of fibers

Comparator method This method involves the comparison of greatly enlarged cross sections with standard cross sections of measured fineness and variability

[22] Hardy, J I, and Wolf, H W Circular No 543, USDA Dec. 1939

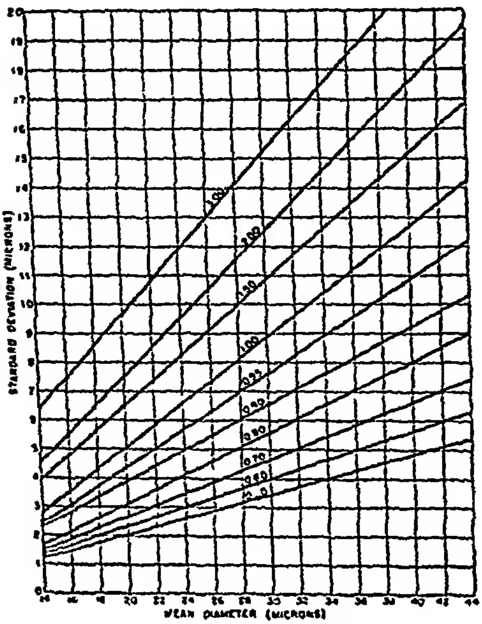

Fig 27 Relationship between mean diameter and standard deviation of wool fibers ranging widely in fineness and variability Numbers on curves represent coefficients of dispersion $\left(\frac{\text{range in diameter}}{\text{mean diameter}}\right)$

Pohle, Hazel, and Keller[23] made a large scale study of both methods and came to the following conclusions: The accuracy of single estimates of fineness by the count and rapid comparator methods was equivalent to that of measuring approximately 75 and 62 fibers, respectively Both are much faster in practice than measuring an equivalent number of fibers Average fiber diameter estimated by both methods appeared to be unbiased, although there was some evidence that the deviations of the finest and the coarsest fleeces from the average were underestimated

Both short-cut methods were *sufficiently* accurate *to distinguish* between uniform and variable fleeces, however, they were not very accurate in discerning small differences in uniformity

Measuring apparatus. For microscopic measurement of the fiber fineness, any projection microscope is suitable which has a movable stage and a fixed body tube with the necessary objective and eye piece to give a magnification of 500 diameters The Bausch and Lomb VH fiber apparatus, as illustrated is especially suitable for this purpose This instrument, which was assembled on the basis of von Bergen's experience, is suitable for any kind of microscopic as well as photomicrographic work in an up-to-date wool laboratory For photomicrographic work it is necessary for the instrument to be in a dark room (Fig 28)

In Europe several instruments have been developed for wool fiber measurements based on projection methods Of these instruments the

[23]Pohle, E M, Hazel, L N, and Keller, H R Circular No 704 United States Department of Agriculture, August 1944

Zeiss Lanameter designed by Franz and Doehner was selected at the International Wool Conference at Warsaw in 1936 as "the sole International standard instrument for arbitrational wool-fineness measurement". In England an instrument quite similar to the VH fiber apparatus is used The fibers are projected onto a white screen where the image is measured by means of a scale.

The English projection microscope differs from the VH instrument in that it has a movable body tube and a fixed stage. It is equipped to give a magnification of 500 diameters Traversing and focusing controls are operated by control cables which provide easy manipulation The screen on which the image is projected can be rotated or clamped when necessary, and the graduated ruler which it carries is free to move diametrically

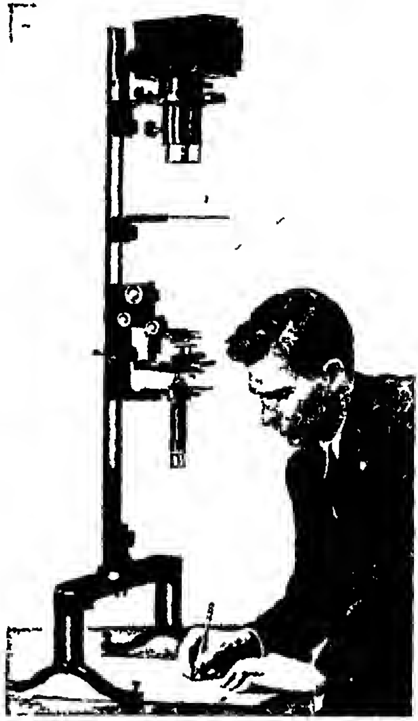

Fig 28 Bausch and Lomb VH fiber measuring apparatus

The equipment used at the U S Department of Agriculture Western Sheep Breeding Laboratory, Dubois, Idaho is shown in Fig 29. This equipment is especially suited for estimating fineness and uniformity by the rapid comparator method as described by Pohle and coworkers The equipment consists of: A, horizontal type of *microprojector* which magnifies, from a cross-section device, the wool sample whose diameter and uniformity are unknown, B, 35-mm. *film-strip projector* with known fiber diameter and uniformity standards for each micron from 16 to 42, which covers the range for domestic grades of wool. The standard lamp house on the 35-mm projector was removed and the projector mounted in a specially constructed large *lamp house* (C) to give greater circulation of cooling air with longer life for the bulb and elimination of all light reflections from the projector; D, *film magazine* constructed to protect film during projection; E, *receiving screen* —the image from the 35-mm film is projected through an orange-colored filter onto a brown paper used as a receiving screen, whereas the

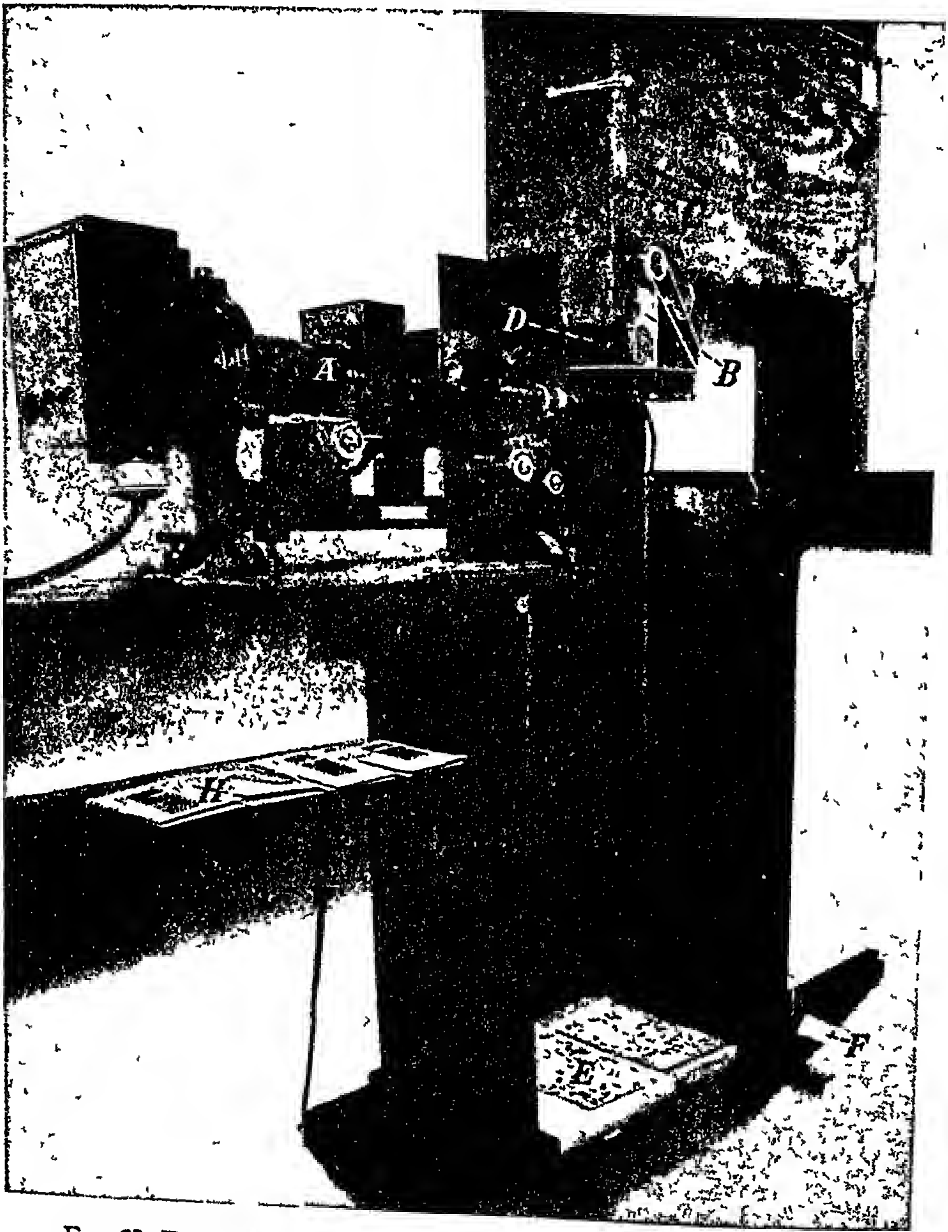

Fig 29 Equipment and apparatus used in rapid comparator method
Courtesy U S Dept of Agriculture Western Sheep Breeding Laboratory, Dubois, Idaho

sample image of unknown diameter is projected onto a dull white paper that gives both images approximately the same light intensity, F, *remote-control knob* for 35-mm projector for ease and rapidity in turning film for matching the proper standard with the unknown; the two projectors are mounted so that they show wool fibers at X 500 magnification, the known standard appearing on the right and the unknown on the left, adjacent to each other; G, *switch* for each projector, H, *cross sections* prepared for projecting and evaluating

TABLE 6 REQUIREMENTS FOR WOOL TOPS[1]

Grade	80's	70's	64's	62's	60's	58's	56's	50's
Fineness range, microns								
Min.	18 1	19 6	21 1	22 6	24 1	25 6	27 1	29 1
Max.	19 5	21 0	22 5	24 0	25 5	27 0	29 0	31 5
Fibers, per cent								
10 to 20 microns, incl, min	60	50	36	27	18	16	9	4
10 to 25 microns, incl, min	92	84						
10 to 30 microns, incl, min			94	88	83	74	64	45
25 1 to 30 microns, incl, max	8							
25 1 to 40 microns, incl, max		16						
30 1 to 40 microns, incl, max	0 25 (0 5)[a]	2	6	12	17			
30 1 to 50 microns, incl, max						26	36	55
40 1 to 50 microns, incl, max		0 25 (0 5)[a]	0 33 (1)[a]	0 50 (1)[a]	0 50 (1)[a]	2	5	10
50 1 and over microns, max						0 75 (1 5)[a]	1 (2)[a]	1.25 (2 5)[a]
Min no fibers per sample required for test	400	400	600	600	800	800	1200	1200

[1] From ASTM Designation D 472-41
[a] Numbers in parentheses represent maximum percentage of fibers of that range permissible in substandard grades

TABLE 7 REQUIREMENTS FOR WOOL TOPS[1]

Grade	48's	46's	44's	40's	36's
Fineness range, microns					
Min	31 6	33 3	34 8	36 6	38 8
Max.	33.2	34 7	36 5	38 7	41 3
Fibers, per cent					
10 to 30 microns, incl, min	34	26	22	16	12
10 to 40 microns, incl, min	77	70	63	55	44
40 1 to 70 microns, incl., max	23	30	37	45	56
60 1 to 80 microns, incl, max	2	2	3	4	4
Min no fibers per sample required for test	1600	1600	1600	1600	1600

[1] Tentative revision of ASTM Designation D 472-41 Submitted June, 1942

Chemical-microscopic methods

Fiber damage. Microscopic methods for determining the various types of damage to wool fibers which occur during the growth of the fiber, the manufacturing processes or during wear, are quite numerous

1. *Alkali damage on wool* The following microscopic chemical tests for testing alkali damage are in use

Allword'sche Reaktion. This reaction is described under the action of chlorine on wool Nonappearance of this reaction indicates alkali damage to the wool in a greater or lesser degree. Conclusions cannot be drawn as to the quantitative degree of damage since the reaction fails even when the alkali action is only slight.

Diazo reaction according to Pauly. Injured wools are colored orange-yellow to a full red in a soda-alkaline diazo solution The amino acid, tyrosin, present in the keratin of the fibrous layer yields this azo color reaction when coupled with diazobenzene sulfonic acid. Mark developed a method from this reaction which permits qualitative and, to a certain extent, quantitative detection of injuries in the individual hairs by microscopical count

This method was simplified by Sieber who found that, in place of the easily decomposed diazo benzene sulfonic acid, the red direct dyestuff Benzopurpurine 4B can be used. However, since the diazo reaction is applicable only to white goods its use is limited

2 *Acid damage on wool* The only chemical microscopic reaction, by which it is claimed acid damaged wool can be detected is the swelling reaction in caustic soda and concentrated ammonia as developed by Krais and Viertel[24] The procedure is as follows:

> The swelling medium is made by dissolving 20 grams of caustic soda in 50 cc concentrated ammonia, with caution and proper cooling. A few drops of this reagent are put near the rim of the cover glass under which are mounted a few wool hairs The caustic soda is drawn over to the fibers by means of filter paper and the swelling reaction which takes place is observed Undamaged wool does not show swelling in less than 8 to 10 minutes, whereas acid-damaged wool swells in 1 to 2 minutes Alkali-damaged wool under the same circumstances shows an even more retarded reaction than undamaged wool, so the discoverers claim the reaction is specifically for acid-damaged wool. As similar reactions take place with oxidized wool, care must be used in evaluating the result when the history of the fiber or fabric is unknown

[24] Krais-Viertel, *Forschungsheft*, 15, German Inst. for the Textile Industry, Dresden, 1933

3 *Oxidation damages.* As already mentioned under chemical tests, oxidation damage can be detected by the high sensitiveness of wool fiber to caustic alkalis The microscopic chemical method makes use of this fact. The amount of swelling caused by N/10 caustic soda can be used as a measure of the degree of damage The difference in the width of the wool fiber before and after the swelling is expressed in per cent

Width is measured in the same manner as described under the width method for measuring fineness. The technique is as follows

> The fibers to be tested are mounted in water, on a slide, and then the width measured As soon as the first measurements are taken, two drops of O.1 N NaOH are put near the rim of the cover glass By means of filter paper the caustic soda is sucked over the fibers from the opposite side of the cover glass This is repeated once more to be sure that all the fibers are in contact with the caustic alkali The swelling takes place immediately and is completed in a few minutes, after which the second measurements of the width are then taken by measuring the same fibers at approximately the same places as in the first reading

To test the damaging action of hydrogen peroxide during bleaching, comparative tests of the chemical (alkali solubility) with the microscopic (swelling) method were made by Harris and von Bergen as shown in Table 8 The method can be used with success for testing chlorinated wool as well as wool damaged by sunlight

TABLE 8

COMPARISON OF ALKALI SOLUBILITY AND SWELLING OF SAMPLES GIVEN SUCCEEDING H_2O_2 TREATMENTS (In per cent)

Sample	*Treatment*	*Alkali-solubility Per cent*	*Swelling Per cent*
1	None	11 1	12 4
2	Bleached with 2 71-vol H_2O_2 for 1½ hr	17 2	14 7
3	Sample 2 bleached with 2 62-vol H_2O_2 for 1½ hr	20 3	18 6
4	Sample 3 bleached with 1 70-vol H_2O_2 for 1 hr	31 4	21.2

Bacteria damage As previously described, bacteria damage can be identified easily with the microscope because of the presence of a great number of split fibers and free cortical cells The approximate bacteria damage can be estimated by counting a definite number of fibers and expressing the number attacked as a percentage

Insect damage Damage caused by *insects* such as moths and carpet beetles is detected by the presence of partly eaten fiber (See Mothproofing.)

The American Society for Testing Materials, in cooperation with the American Association of Textile Chemists and Colorists, has worked out the methods of test for resistance of textile fabrics and yarns to insect pests [25]

Photo-microscopy.

For permanent records of microscopic work and protection in arbitration, purchasers' disputes and court cases, photomicrographs are convincing and of great value. Photo-microscopic methods are practically the same as in the standard photographic procedures The only difference is that instead of using an ordinary camera with lens and housing the lens is replaced by microscope The technique necessary to produce satisfactory photo-micrographs can only be acquired through long practical experience The fundamental rule is great cleanliness of all lenses, mirrors, slides and cover glasses used, because any dust particles, and finger marks will show and distort the picture Plates most suitable for this work are the Wratten M plates manufactured by Eastman Kodak Corp For good detail the use of filters is essential A green filter gives the best results in most instances Eastman recommends also a special developer Success in this kind of work depends much on patience and attention to small details, as well as care

Fig 30 Wool blend cross-section made directly on photostat paper (x500)

[25] A S T M Designation D582-45T

in keeping a record of each photo. For current work and laboratory records the simplest and most economical way is to use a fiber measuring projector and photograph the image on a photostat paper to produce negatives. These negatives can be developed, rinsed and dried in an hour and are, in many instances, just as satisfactory as prints made from plates. (Fig. 30.)

Infra-red photography When the surface structure of black or very dark dyed fibers needs to be studied, the normal way of stripping the color cannot be used, because the stripping may damage the surface structure In such cases, the use of infra-red plates will disclose the unchanged structure of the fiber.

Microscopy with fluorescent light Since the introduction of simple and cheap lamps, the use of fluorescent light has found wide application in the detection of mildew growth, for the identification of dyes in color mixtures, and in the analysis of the numerous stains caused by oils and metals

Statistical Analysis.

The use of precision methods and the statistical analysis of results is considered a necessity today in textile technology Ten years ago only a few in the textile field realized the importance of this work, but today it is part of the daily routine of most textile laboratories and the basis of the quality control program of many mills As E R Schwarz[26] so well stated:

> This must be so because of the errors involved in any form of testing. These errors can only be dealt with intelligently by the application of precision studies and by the statistical treatment of the data Further, the materials themselves are variable and since to be of value many tests must be comparative, the significance of the results must be determined and their degree of correlation worked out No report of research results in the field of textiles particularly can be considered complete without a precision discussion of method, equipment and results Not only how much, but how good a measurement must be reported Far too many tests are made daily by well intentioned but uninformed workers who obtain results upon which changes of vital concern to their particular branch of the industry will be based Far too often

[26] Schwarz, E R, in address to Annual Meeting of Am Assn of Textile Chemists and Colorists, Philadelphia, 1937

these results are of no practical significance, and their practical application results in a black eye for research in general, and that partial research in particular.

During the war years many textile concerns adopted statistical meth

TABLE [illegible]

FLOW SHEET OF MANUFACTURE AND TESTING PROCEDURE

Worsted 18 processes		*Woolen* [illegible] processes	
Raw wool	1	Raw wool	1
Sorting		Sorting	
Scouring		Scouring	
Combing	1, 2, 3	Stock dyeing	
Top dyeing	3	Carding	1
Spinning	4, 5, 6	Spinning	4, 5, 6
Weaving		Weaving	
Grey goods	4, 7, 8, 9	Grey goods	4, 7, 8, 9
Fulling	10	Fulling	10
Washing	4	Washing	4, 12
Crabbing		Carbonizing	
Drying		Neutralizing	4
Specking	11	Decating	
Shearing		Drying	
Decating		Shearing	
Final examining		Pressing	
Finished cloth	4, 7, 8, 9, 13, 14, 15, 16, 17	Final examining	
		Finished cloth	4, 7, 8, 9, 12, 13, 14, 15, 16

Key	*A S T M Standards*[1]
1 Fiber fineness	D 419-37, D 472-41
2 Fiber length	D 519-40
3 Tensile strength (bundle)	
4 Breaking strength	D 39-39, D 403-39, D 404-39
5 Yarn number (count)	D 39-39, D 403-39, D 404-39
6 Twist	D 39-39, D 403-39, D 404-39
7 Ounce weight	D 39-39
8 Piece length and weight	
9 Picks per in	D 39-39
10 Fulling time	
11 Specking time	
12 Crocking	A A T C C Standard method
13 Width	D 39-39
14 Ends per in	D 39-39
15 Weight and length loss	
16 Color fastness to light	D 506-41
17 Sponging	

[1] 1942 Book of A S T M Standards, Part III.

ods to govern their control of product quality They achieved not only a more uniform end product but made considerable savings by holding the product close to specification.

The plan used at the Forstmann Woolen Company for quality control of production of the 18 oz. olive drab U S. Army serge and the 16 oz. navy blue U. S. Navy melton is given as an example

To show the points of control testing in the general manufacturing routines for the two cloths, the preceding flow sheet (Table 9) is given The test procedures for the various processes are found by reference to the key.

The control led to a study of the factors influencing the breaking strength of the two fabrics. It was found that the raw material is one of the primary factors. Yarns from fine domestic wools are generally weaker, due to their shorter fiber length, than Australian or Cape wool yarn of similar fineness. A change in the blend affected the strength level of the yarns and pieces as a whole. In the case of a 50/50 domestic-Australian wool blend, the strength increased 5 to 8 per cent over that of the 100 per cent domestic blend.

The method chosen to dye the wool or top is another primary factor in the ultimate strength level. The length of time the wool is in contact with the dye bath and the temperature of the dye bath are the two most important factors In this connection the metachrome dyeing process with its shorter time produced 6 to 8 per cent stronger pieces than the top chrome dyeing process Continuous indigo dyeing with its short immersion time and low temperature yielded pieces which averaged about 25 per cent above the specified strength In the case of the indigo-chrome combination the strength level was 10 to 15 per cent above, whereas the chrome dyed wool produced pieces which were approximately 10 per cent below, specifications

The variations introduced into the strength picture by the spinning process are of a varied nature The yarn count directly affects not only the strength of the yarn itself but also that of the fabrics. A change of half a count metric in the two-ply serge yarn resulted in a 4 per cent increase of the yarn strength

Therefore, control over yarn count, that is, holding yarn fluctuations within small limits, will result in a reduction of the eventual variations in fabric strength. It was shown that the ply worsted yarn, by reason of the doubling twist, is about twenty-five per cent stronger than twice the single yarn strength

The yarn produced on ring spinning frames is two per cent stronger than the yarn spun on mules The amount of the difference, nevertheless, is not large enough to be of great importance

The yarn breaking strength varied directly with the amount of twist up to a certain maximum. Further insertion of twist then reduced the breaking strength A definite end point for practical strength increase exists for each yarn size. Small differences in twist within the range that occurs in normal production have little or no influence on the strength of the yarn It is only when large differences in twist occur that an effect on the strength will be noticed.

By the comparison of variations of worsted and wool yarn, indications of the inherent manufacturing uniformity levels and variations have been revealed By reason of the complexity of the worsted yarn system small inequalities tend to be averaged out through the long preparatory processes before actual spinning takes place This is not case in the woolen system Variations in roving off the cards is directly transmitted to the yarn as there are no intervening equalizing operations Assignable causes of variations of this type, due to the manufacturing process, can be minimized by strict control but not completely eliminated without radical alteration of the process itself.

The foregoing comments on manufacturing operations previous to weaving indicate that the material with which the weaver has to work is by no means uniform Since weaving is a combining operation, the yarn variations are carried over directly into pieces and form a part of the ultimate variations found in finished cloth

To bring the factors influencing the breaking strength of Army and Navy cloth to a common ground, the coefficients of variation, that is, the relative variabilities, previously mentioned, are grouped in Table 10 The coefficients are completely different for the two spinning systems Wool spinning has more than twice the variability of the worsted system This generalization holds true for the piece goods The data show that the strength variations in the yarns are directly responsible for the strength variations in the cloth. However, the worsted tends to increase in variability as manufacturing progresses, while, on the other hand, the trend in the woolen system is just the reverse Evidently,

TABLE 10 COEFFICIENTS OF VARIATION (PER CENT) THROUGHOUT MANUFACTURING

		Worsted					
		Domestic		*Blend*		*Woolen*	
		Warp	*Filling*	*Warp*	*Filling*	*Warp*	*Filling*
Yarn	Ring	55		34			
	Mule	.	45		40	86	87
Pieces	Gray	44	40	44	40	58	70
	Finished	43	52	45	44	60	81

the reaction of the product of wool spinning is toward a loss of variability, that is, a gain in uniformity

The effect of fulling on worsted pieces is just opposite to that on woolen pieces While the woolens gain in absolute strength, worsteds remain unchanged or become weaker, though both show a loss when breaking strength per thread is considered.

Carbonizing and neutralizing in piece form, when properly controlled, have very little effect. The effect of surface disturbing operations, such as sanding and napping, can be measured directly by the change in breaking strength Operations designed to produce a certain touch such as decating and pressing have a complicated influence, the greatest part of which is due to moisture content of the cloth when testing is performed under mill conditions There is a definite peak strength to be associated with moisture content of approximately 8 per cent. Higher or lower moisture content yields lower strength. The moisture level of control testing at 65 per cent relative humidity and 70° F. is not that of maximum strength.

The results of control testing throughout manufacturing permitted the setting of minimum strength averages to be maintained The figures in Table 11 give these levels The finished piece averages[27] had to be set high enough so that the normal fluctuations would not cause any piece to fail specifications The yarn and raw piece averages can then be adjusted to give the desired finished piece level Greater standard deviations than those given necessitate the maintenance of higher

TABLE 11. PREDICTION OF STRENGTH

	Worsted		*Woolen*	
	Warp	*Filling*	*Warp*	*Filling*
Yarn strength needed				
Average	166[a]	180	87	72
Standard deviation	7 0	7 0	8 0	7 0
Gray piece strength needed				
Average	143	130	55	52
Standard deviation	7 0	6 0	4 0	5 0
Finished piece strength needed to pass specification 100 *per cent*				
Specification	120	110	58	46
Average	141	128	70	61
Standard deviation	7 0	6 0	4 0	5 0

[a] Actual production = 193 lb

[27] According to the standard deviations given, these are 3 sigmas above the specification

average levels whereas smaller standard deviations permit maintenance of an average level closer to the specified minimum. From an economical point of view, this is the goal to achieve.

The use of statistical analysis in mill quality control work is the best weapon with which to overcome the rule-of-thumb methods still prevailing in most of our woolen and worsted plants But the successful use of that weapon depends on a carefully trained staff of technologists, who must not only be able to interpret the test result obtained but also to sell the use of the result to the practical mill man

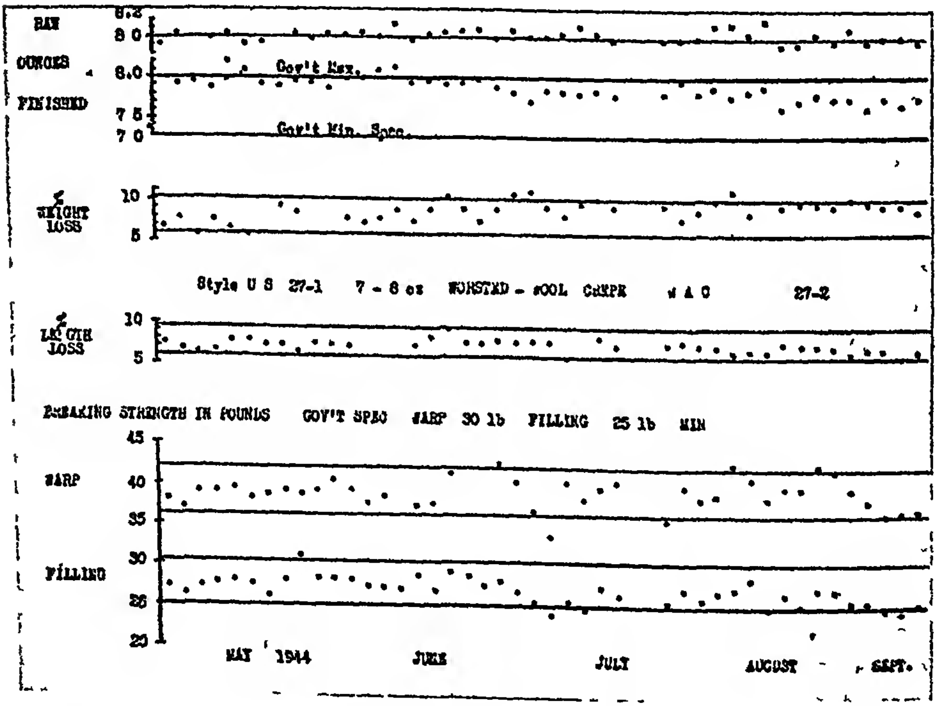

Fig 31 Control charts of worsted-wool crepe U S Army W A C cloth

One of the best ways of presenting data to the mill man is the use of control charts Figure 31 shows the control charts used in the study of the production fluctuation of the U. S Army W A C cloth in the Forstmann Woolen Company finishing plant They illustrate much better than figures can ever do, whether a product is in control or not.

The American Society for Testing Materials is insisting upon considerations of precision and upon the statistical treatment of data for its textile work as well as for its other branches of activity and publishes a Manual on Presentation of Data through their Committee E-1 on Methods of Testing.

Committee D-13 of the A.S T.M. has a special sub-committee B-5 for statistical analysis for textile tests, which has done a great deal of work in developing the mathematical foundation for measuring fineness and length and for the identification of fibers. One of the latest works of this sub-committee is the recommended practice for calculating the number of tests to be specified in determining average quality of a textile material Such methods were applied in numerous discussions in this book such as those on wool fineness, length and strength measurements

Chapter 24

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WOOL TRADE ASSOCIATIONS

AMERICAN ANGORA GOAT BREEDERS ASSOCIATION, Rock Springs, Texas
AMERICAN ANGORA RABBIT BREEDERS COOPERATIVE, Palmer Lake, Colo
AMERICAN ASSOCIATION OF TEXTILE CHEMISTS & COLORISTS, Lowell, Mass
AMERICAN ASSOCIATION OF TEXTILE TECHNOLOGISTS, 70 E 45th St., N Y C
AMERICAN WOOL COUNCIL, 1450 Broadway, N Y C
BOSTON WOOL TRADE ASSOCIATION, 263 Summer Street, Boston, Mass
BRAND NAMES RESEARCH ASSOCIATION, 119 West 57th St, N. Y. C
CALIFORNIA WOOLGROWERS ASSOCIATION, 595 Mission St., San Francisco, Calif
CANADIAN CO-OPERATIVE WOOL GROWERS, LTD, 217 Bay Street, Toronto
CANADIAN WOOLEN & KNIT GOODS MANUFACTURERS ASSOCIATION, 80 Richmond St, W Toronto
CLOTHING MANUFACTURERS ASSOCIATION OF THE U S A 220 5th Ave, N Y C.
COLORADO WOOL GROWERS ASSOCIATION, Fort Collins, Colo
DOMINION WOOL DEALERS ASSOCIATION, LTD, 217 Bay Street, Toronto
DOWNTOWN TEXTILE CREDIT GROUP, INC., 40 Worth Street, N Y C
EASTERN MAINE WOOLEN OVERSEERS' ASSOCIATION, Guilford, Me
FEDERATION LANERA ARGENTINA, 428 Cangallo, Buenos Aires
FELT ASSOCIATION OF AMERICA, 366 Madison Ave., N Y C
GREEN MOUNTAIN TEXTILE OVERSEERS' ASSOCIATION, Proctorsville, Vt
HATTERS FUR CUTTERS' ASSOCIATION, 29 Clover St, Newark, N J
IDAHO WOOL GROWERS ASSOCIATION, Boise
INSTITUTE OF CARPET MANUFACTURERS OF AMERICA, INC., N Y. C
INTERNATIONAL ASSN OF GARMENT MANUFACTURERS, 260 Broadway, N Y C
INTERNATIONAL WOOL SECRETARIAT, 201 East 57th St., N Y C
KENTUCKY WOOL GROWER CO-OPERATIVE ASSOCIATION, Cynthiana, Ky
MAINE WOOLEN & MFG ASSOCIATION.
MASTER DYERS' ASSOCIATION, 3419 Richmond St, Philadelphia, Pa.
MICHIGAN CO-OPERATIVE WOOL MARKETING ASSOCIATION, 506 N Mechanic St, Jackson, Mich
MONTANA WOOL GROWERS' ASSOCIATION, Deer Lodge, Montana
NATIONAL ASSN OF WASTE MATERIAL DEALERS, INC., Times Bldg, N. Y C
NATIONAL ASSN. OF WOOL FIBRE MANUFACTURERS, 2300 Washington St, Newton Lower Falls, Mass
NATIONAL ASSN OF WOOL MANUFACTURERS, 386 Fourth Ave., N. Y C
NATIONAL ASSN OF WOOLEN & WORSTED OVERSEERS, Fulton, N Y
NATIONAL TEXTILE PROCESSORS GUILD, INC., 51 Chambers St., N Y C
NATIONAL WOOL GROWERS ASSOCIATION, Salt Lake City, Utah
NATIONAL WOOL MARKETING ASSOCIATION, Boston, Mass
NATIONAL WOOL TRADE ASSOCIATION, 263 Summer St., Boston, Mass
NEW MEXICO WOOL GROWERS ASSOCIATION, San Mateo, New Mexico

PACIFIC WOOL GROWERS ASSOCIATION, Portland, Oregon.
PAPERMAKERS FELT ASSOCIATION, c/o Appleton Woolen Mills, Appleton, Wis
PHILADELPHIA WOOL AND TEXTILE ASSOCIATION, Phila, Pa
SOFT FIBRE MANUFACTURERS INSTITUTE, INC, 9 Rockefeller Plaza, N Y. C
TENNESSEE WOOL GROWERS' ASSOCIATION, Franklin, Tenn
TEXAS ANGORA GOAT RAISERS' ASSOCIATION
TEXAS SHEEP AND GOAT RAISERS' ASSOCIATION, San Angelo, Texas
TEXAS WOOL AND MOHAIR MARKETING ASSOCIATION, San Angelo, Texas
TEXTILE COLOR CARD ASSOCIATION OF THE U S, INC., 200 Madison Ave, N.Y.C
TEXTILE DISTRIBUTORS INSTITUTE, INC., 469 7th Ave., N Y. C.
TEXTILE ECONOMICS BUREAU, INC., 10 E 40th St., N. Y. C.
TEXTILE EXHIBITORS ASSOCIATION, INC., 925 Park Sq Bldg., Boston, Mass.
TEXTILE EXPORT ASSOCIATION OF THE U S, 40 Worth St., N. Y. C.
TEXTILE RESEARCH INSTITUTE, 10 E. 40th St., N. Y C
TEXTILE REFINISHERS ASSOCIATION, 1450 Broadway, N Y C.
TEXTILE WASTE EXCHANGE, Box 1611, Atlanta, Ga.
U S TRADE-MARK ASSOCIATION, 522 5th Ave., N Y. C
UTAH WOOL GROWERS' ASSOCIATION, Salt Lake City.
WASHINGTON WOOL GROWERS' ASSOCIATION, Yakima, Washington
WISCONSIN CO-OPERATIVE WOOL GROWERS' ASSOCIATION
WOOL ASSOCIATES OF THE N Y COTTON EXCHANGE, 60 Beaver St, N Y C.
WOOL CLUB OF N. Y, INC, 260 W. Broadway, N Y. C
WOOL HAT MFRS ASSOCIATION OF AMERICA, c/o Lamb & Lerch, N Y C
WOOL KNIT ASSOCIATES, INC., 366 5th Ave, N Y. C
WOOL YARN JOBBERS' CREDIT ASSOCIATION, INC., 381 4th Ave., N Y C.
WOOLEN HOSIERY INSTITUTE OF AMERICA, c/o Handknit Hosiery Co, Sheboygan, Wis
WOOLEN JOBBERS' ASSOCIATION, INC, 32 Broadway, N Y C
WOOLEN WHOLESALERS' NATIONAL ASSOCIATION, INC., 32 Broadway, N Y C

WOOL MAGAZINES

AMERICAN DYESTUFF REPORTER, New York, N. Y. (Bimonthly)
AMERICAN WOOL & COTTON REPORTER, Boston, Mass (Weekly)
CALIFORNIA WOOL GROWER, 151 Mission Street, San Francisco, Calif
COLORADO WOOL GROWER & MARKETER, Box 553, Fort Collins, Col.
COOPERATIVE WOOL GROWERS OF SOUTH DAKOTA, 101-27th Ave., S E. Minneapolis, Minnesota.
FELT FACTS by Felt Association, New York (Periodically)
FIBRE AND FABRIC, Cambridge, Mass (Weekly)
IDAHO WOOL GROWERS BULLETIN, Boise, Idaho
MAKING THE GRADE WITH WOOL Lavenson Bureau, 12 So 12th St, Philadelphia, Pennsylvania

MONTANA WOOL GROWER, Box 1693, Helena, Montana.
NATIONAL WOOL GROWER, Salt Lake City 1, Utah (Monthly)
NEW MEXICO STOCKMAN, Albuquerque, New Mexico
PACIFIC WOOL GROWER, 734 N W 14th St, Portland 9, Oregon
SHEEP & GOAT RAISER, San Angelo, Texas
SHEEP BREEDER, 10 Watson Place, Columbia, Missouri
SHEEP BREEDER MONTHLY, Chicago, Ill (Monthly)
TEXAS MOHAIR WEEKLY, Rocksprings Texas (Weekly)
TEXTILE WORLD McGraw-Hill Publishing Corp, New York (Monthly)
WESTERN LIVE STOCK JOURNAL, 4511 Produce Plaza, Los Angeles 11, Calif
WOOL DIGEST by International Wool Secretariat, New York, N. Y (Monthly)
WOOL FACTS by American Wool Council, Inc, New York, N Y (Periodically)
WYOMING WOOL GROWER, McKinley, Wyoming

AMERICAN WOOL FILMS

BOTANY CLOTHES THE NATION 16 mm Sound and color Botany Worsted Mills, Passaic, N J No charge

CA-VEL-CADE. 16 mm Sound Collins & Aikman Corp, 200 Madison Avenue, New York, N Y No charge

——— 16 mm Encyclopedia Britannica Films Inc Black and white, sound Price $45 00

COOPERATIVE WOOL—FROM FLEECE TO FABRIC Three reels 16 mm 35 mm Sound (1938) U S Dept of Agriculture, Washington, D C No charge.

DEERING MILLIKEN WOOLEN MOVIE 16 mm Sound and color Deering, Milliken and Company, 45 7th Avenue, New York, N Y No charge

GOLDEN FLEECE One reel 16 mm Sound Ideal Pictures Corp, 28 East 8th Street, Chicago, Ill Sheep raising in Australia

SCIENTIFIC STOCK BREEDING ½ reel 35 mm Silent Wholesale Film Service, 48 Melrose Street, Boston, Mass Raising thoroughbred sheep at Purdue University

SHEEP SHEARING 16 mm Sound, black and white Castle Films, Div, United World Films, Inc, 30 Rockefeller Plaza, New York 20 Price $32 87

WOOL—MARKETING AND MANUFACTURE. 3 reels 35 mm Silent (1932) U S Dept of Agriculture No charge

WOOLEN GOODS One reel Silent Eastman Kodak Company, Teaching Films Division, 343 State Street, Rochester, N Y

A WOOLEN YARN One reel 16 and 35 mm Silent General Electric Company, 1 River Road, Schenectady, N Y No charge

Tariff Schedules

RATES OF DUTY AS OF JULY 1, 1946, AND OF JANUARY 1, 1948[1] ON WOOL AND WOOL MANUFACTURES IMPORTED INTO THE UNITED STATES

The following rates are those effective as of July 1, 1946, because of inclusion originally in the Tariff Act of 1930, or by reason of modifications in the provisions of Schedule 11 effected either by Presidential proclamation under authority of Section 336 (the rate adjustment provision) of the Tariff Act, or by trade agreement treaties concluded pursuant to amendments to the Tariff Act of 1930 providing for such agreements While trade agreements are concluded with individual countries, reductions in tariff rates granted by the United States to one country through a trade agreement are automatically extended, by direction of the President, to the products of all other nations Products of countries found by the President to be discriminating against United States commerce are subject to the rates in effect prior to any modification pursuant to trade agreements Germany was listed as a discriminating country from October 15, 1935, to May 30, 1942, and Australia was so listed from August 1, 1936, to February 1, 1938 At present the provisions of the Trading with the Enemy Act and the orders and regulations issued pursuant thereto effectively prevent Germany and other enemy countries from deriving any benefit from tariff reductions effected by trade agreements

[1] On January 1, 1948 new rates of duty became effective according to the General Agreement on Tariffs and Trade signed at Geneva October 30 1947 They are applicable to all most favored nations including Argentina and Uruguay

The new rates as well as the rates which were effective in 1946 at the date of the printing of the second edition are shown on the following pages

RATES OF DUTY ON WOOL AND WOOL MANUFACTURES IMPORTED INTO THE UNITED STATES

Paragraph of Tariff Act	*ITEM*	*Cents Per Pound of Clean Content*[1] 1946	1948
1101 and 1102	Wool and similar hair[2]		
	In the grease or washed.		
	Wool of grades[3] finer than 44s, and hair of the Angora goat, and other like animals (except camel, cashmere, alpaca, llama and vicuna).	34	25½
	Camel's hair[4]	24	12
	Alpaca, llama, vicuna, and cashmere hair	18	18
	Wool of grades[3] 40s to 44s, with a tolerance in each bale or package of not more than 10 per cent of wool not finer than 46s	17	17
	Carpet wools, and all other wools not finer than 40s, with a tolerance in each bale or package of not more than 10 per cent of wools not finer than 44s, used other than in carpets, rugs, etc.[4]	13	13
	Scoured: 3 cents more per pound than in the grease except wool 46s and finer which is 2¼c and camel hair which is 1½c		
1106	Carbonized: 27¾ cents plus 6¼ per cent ad valorem		
1101 and 1102	Sorted or matchings, if not scoured, other than skirtings: 1 cent more per pound than similar wools in grease except wool finer than 44s which is ¾c		
	On the skin: 2 cents less per pound than similar wools in the grease except wool finer than 44s which is 1½c.		

		Cents Per Pound 1946	1948
1105	Wool waste and substitutes:		
	Top, slubbing, roving, and ring waste	34	28
	Garnetted waste	18	14½
	Noils, carbonized	21	17
	Noils, not carbonized	16	12
	Thread or yarn waste	15	11½
	Card or burr waste, carbonized	18	14½
	Card or burr waste, not carbonized	14	10½
	Shoddy and wool extract	14	14
	Mungo	9	9
	Woolen rags.	9	9
	Flocks	5	3½
	All other wastes, n s p f	14	10½

See footnotes at end of table

RATES OF DUTY ON WOOL AND WOOL MANUFACTURES IMPORTED INTO THE UNITED STATES (*Continued*)

Paragraph of Tariff Act	ITEM	Compensatory rate Cents per Lb 1946	Compensatory rate Cents per Lb 1948	Protective rate % Ad valorem 1946	Protective rate % Ad valorem 1948
1106	Wool if carbonized or advanced in manufacture beyond the washed or scoured condition, including tops, but not further advanced than roving .	37	27¾	12½	6¼
1107	Yarns of wool, other than Angora rabbit hair.	—	27¾		12½
	Value Not over $1 00 per pound .	30	40	30	15
	$1 01-$1 50 per pound .	36	40	30	15
	Over $1 50 per pound . . . . ., .	40	40	30	15
	Yarns of Angora rabbit hair	40	30	25	20
	Woven fabrics wholly or in chief value of wool:[6]			-	
1108	Not over 4 oz per square yard:				
	Not cotton warp	50	37½	37½	25
	Cotton warp .	40	30	37½	25
1109(a)	Over 4 oz per square yard (other than woven green billiard cloths weighing 11-15 oz per square yard)				
	Value Not over $1 25 per pound	40	37½	45	25
	$1 26-$2 00 per pound .	50	37½	40	25
	Over $2 00 per pound . ..	50	37½	35	25
	Woven green billiard cloths, in the piece, weighing more than 11 oz., but not more than 15 oz. per square yard, wholly of wool ------------	50		40	..
1109(b)	Felts, etc , woven, in chief value of wool, for machine clothing:	-			
	Value. Not over $1.25 per pound	50	37½	25	20
	$1.26-$2 00 per pound	50	37½	27½	20
	Over $2 00 per pound	50	37½	30	20
1110	Pile fabrics and manufactures thereof	44	33	40	25
1111	Blankets, etc [7] not over 3 yards in length				
	If hand woven	20	20	20	20
	Otherwise:				
	Value Not over $1 00 per pound	30	30	36	30
	$1 01-$1 50 per pound	33	30	36	30
	Over $1 50 per pound	40	30	36	30
1112	Felts, not woven:	-			
	Value Not over $1 50 per pound	30	22½	30	20
	Over $1 50 per pound	40	30	35	20

See footnotes at end of table.

RATES OF DUTY ON WOOL AND WOOL MANUFACTURES IMPORTED INTO THE UNITED STATES (*Continued*)

Paragraph of Tariff Act	*ITEM*	*Compensatory Rate Cents per Lb* 1946	1948	*Protective Rate % Ad valorem* 1946	1948
	Miscellaneous trimmings, etc.:				
1113	Fabrics wholly or in chief value of wool, with fast edges, not exceeding 12 inches in width, including cords, braces, cords and tassels, garters, suspenders, tubings	50	37½	40	20
1529	Braids, edgings, embroideries, flouncings, fringes, galloons, gimps, insertings, laces, nettings, ornaments, trimmings, etc			90	25-90
1114	Knit Goods.[8]				
1114(a)	Knit fabrics in the piece				
	Value Not over $1 00 per pound	33	25	40	20
	Over $1 00 per pound	50	37½	40	20
(b)	Hose and half hose, not embroidered,[9] finished or unfinished				
	Value Not over $1 75 per dozen pair	40	30	35	20
	$1 75-$3 50/doz pair 1948 $1 75-$4	50	37½	35	20
	Over $3 50/doz pair 1948 over $4	50		25	
	Gloves and mittens, finished or unfinished				
	Value Not over $1 75 per dozen pair[10]	40	30	35	17½
	$1 76-$3 00/doz pair 1948	50	37½	30	50
	Over $3 00/doz pair over $1 75	50	37½	40	25
(c)	Knit underwear				
	Value Not over $1 75 per pound	40	30	30	20
	Over $1 75 per pound	50	37½	30	20
(d)	Outerwear and other articles, knitted or crocheted and n s p f				
	Hats, bonnets, caps, berets, and similar articles, finished or unfinished, not in part of wool felt				
	Value Not over $2 00 per pound	44	33	30	22½
	Over $2 00 per pound	50	37½	50	25
	Infants outerwear (other than headwear), finished or unfinished				
	Value Not over $2 00 per pound	44	..	45	.
	Over $2 00 per pound				
	Made or cut from Jersey fabric	50	37½	25	25
	Otherwise	50	..	50	..

See footnotes at end of table

RATES OF DUTY ON WOOL AND WOOL MANUFACTURES IMPORTED INTO THE UNITED STATES (*Continued*)

Paragraph of Tariff Act	*ITEM*	*Compensatory Rate Cents per Lb* 1946	1948	*Protective Rate % Ad valorem* 1946	1948
1114(d)	Other wool knit outerwear, n s p f				
	Value Not over $2 00/lb } Not over $5 00/lb	44	37½	45	30
	$2 01-$5 00/lb	50		40	
	Over $5 00 per pound	50	37½	30	20
1115	Other wearing apparel:				
1115(a)	Clothing, not knit or crocheted, except hats and hat bodies				
	Value Not over $4 00 per pound	33	25	30	25
	Over $4 00 per pound	50	37½	30	25
(b)	Hat bodies of wool not knit or crocheted nor made of knit, crocheted, or woven material				
	If pulled or stamped	40 Plus 12½c per article	40	55	55
	If blocked, trimmed or finished				
	Value Not over $12 00 per dozen	40 Plus 8c per article	30	55	40
	Over $12 00 per dozen	40 Plus 8c per article	30	40	30
	Otherwise	40	40	55	55
	Carpets and rugs:				
1116(a)	Carpets, rugs, mats, not made on power-driven looms (Oriental, Axminster, Savonnerie, Aubusson, and other carpets, rugs, and mats)	15 cents square foot 25 cents per square foot, but not less than 22½ per cent ad valorem			
(b)	Carpets, rugs, mats, produced on power-driven looms (Oriental weave and chenille Axminster)			40	30
1117(a)	Carpets, rugs, mats: Axminster, n s p f, Wilton, Brussels, velvet, tapestry, and carpets, rugs and mats of like character			40	30
(b)	Ingrain carpets, rugs and mats or art squares and floor coverings of like character, n s p f			25	

See footnotes at end of table.

RATES OF DUTY ON WOOL AND WOOL MANUFACTURES IMPORTED INTO THE UNITED STATES (*Continued*)

Paragraph of Tariff Act	*ITEM*	*Compensatory Rate Cents per Lb.*		*Protective Rate % Ad valorem*	
		1946	1948	1946	1948
1117(c)	All other floor coverings, including mats and druggets, n s p f ·				
	Value· Not over 40 cents per square foot	.		30	15
	Over 40 cents per square foot				
	Mohair			40	25
	Other			60	40
1118	Screens, hassocks, and all other articles, wholly or in part of carpets, rugs, or mats, n s p f	.		30	15
1119	Tapestries and upholstery goods (not pile fabrics) Dutiable as in pars 1108 and 1109(a)	.	37½		25
1120	Cloth samples measuring not more than 104 square inches			25	12½
	All manufactures wholly or in chief value of wool, n.s p.f.			50	40
1121	Defines scope of term "wool" as applied to manufactures				
1122	Fabrics (except printing-machine cylinder lapping in chief value of flax), in the piece or otherwise, containing 17 per cent or more in weight of wool, but not in chief value thereof, and whether or not more specifically provided for The portion by weight of wool dutiable as in pars 1108 or 1109 of the Tariff Act, the remaining weight dutiable according to the schedules applying to the other materials				

n s p f —Abbreviation for "not specially provided for"

[1] The words "clean content" shall mean all that portion of the wool or hair which consists exclusively of wool or hair free of all vegetable and other foreign material and containing 12 per cent by weight of moisture and 1½ per cent by weight of material removable from the wool or hair by extractions with alcohol, and having an ash content not exceeding one-half of one per cent by weight (*Customs Regulations, Sec 13 11 (a) (1)*)

[2] Wools and hair *in the grease* shall be considered such as are in their natural condition as shorn from the animal, and not cleansed otherwise than by shaking, willowing, or burr picking, *washed* wools and hair shall be considered such as have been washed, with water only, on the animal's back or on the skin, and all wool and hair, not scoured, with a higher clean yield than 77 per centum shall be considered as washed, *scoured* wools and hair shall be considered such as have been otherwise cleansed (not including shaking, willowing, burr picking, or carbonizing), *sorted* wools or hair, or *matchings*, shall be wools and hair (other than skirtings) wherein the identity of individual fleeces has been destroyed, except that skirted fleeces shall not be considered sorted wools or hair, or matchings, unless the backs have been removed (*Par 1101 (b), Tariff Act of 1930*)

Rules and Regulations

Under the

WOOL PRODUCTS LABELING ACT OF 1939

Promulgated by the Federal Trade Commission

Effective July 15, 1941

DEFINITIONS

RULE 1—*Terms Defined*

As used in these rules, unless the context otherwise specifically requires,—

(*a*) The term "Act" means the Wool Products Labeling Act of 1939 (approved October 14, 1940, Public No 850, 76th Congress, Third Session)

(*b*) The terms "rule," "rules," "regulations" and "rules and regulations" mean the rules and regulations prescribed by the Commission pursuant to the Act

(*c*) The definitions of terms contained in section 2 of the Act shall be applicable also to such terms when used in rules promulgated under the Act.

LABELING

RULE 2—*General Requirement*

Each and every wool product subject to the Act shall be marked by a stamp,

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[3] The Official Standards of the United States for grades of wool as established by the Secretary of Agriculture on June 18, 1926, pursuant to law, shall be the standards for determining the grades of wool (*Par. 1101 (b) (5), Tariff Act of 1930*).

[4] Carpet wools and camel hair may be imported under bond without payment of duty for use "in the manufacture of press cloths, camel's hair belting, knit or felt boots, heavy fulled lumbermen's socks, rugs, carpets, or any other floor coverings" If such imported wools are used subsequently in items other than those specified, the regular duties shall be levied (*Customs Administrative Act of 1938*).

[5] If any bale or package contains wools, hair, wool wastes, or wool waste material, subject to different rates of duty, the highest rate applicable to any such part shall apply to the entire contents of such bale, except as provided (tolerances) in paragraphs 1101 and 1102 (*Par 1103 of Tariff Act of 1930*)

[6] Cloth, in chief value of cotton, containing wool, 40 per cent ad valorem (*Par 906, Tariff Act of 1930*, as modified by Trade Agreement with United Kingdom) Fabrics containing 17 per cent or more in weight of wool, but not in chief value thereof, see Paragraph 1122

[7] Includes carriage and automobile robes and steamer rugs Blankets over three yards in length are considered as woven fabrics and are dutiable as for Paragraph 1109(a)

[8] If wholly or in chief value of rayon or other synthetic textile, dutiable under Paragraph 1309

[9] If embroidered, dutiable under Paragraph 1529(a) as modified by Trade Agreement with United Kingdom, at 65 per cent ad valorem if valued at not more than $3 50 per dozen pairs, and 50 per cent ad valorem if valued at more than $3 50 per dozen pairs

[10] By a proclamation of the President of the United States dated February 21, 1936, and effective March 22, 1936, the basis for assessing the duty on wool knit gloves and mittens valued at not more than $1 75 per dozen pairs was changed from the foreign value to the American selling price as defined in Section 402(g) of the Tariff Act of 1930 of similar merchandise manufactured or produced in the United States

tag, label, or other means of identification, in conformity with the requirements of the Act and the rules and regulations thereunder

RULE 3—*Required Label Information*

The marking of wool products under the Act shall be in the form of a stamp, tag, label, or other means of identification, showing and displaying upon the product the required information legibly, conspicuously, and nondeceptively The information required to be shown and displayed upon the product in the stamp, tag, label, or other mark of identification, shall be that which is required by the Act and the rules and regulations thereunder, including the following

(*a*) The fiber content of the product specified in section 4(*a*) (2) (A) of the Act

(*b*) The maximum percentage of the total weight of the wool product of any nonfibrous loading, filling or adulterating matter as prescribed by section 4(*a*) (2) (B) of the Act

(*c*) The name of the manufacturer of the wool product and/or the name of one or more persons subject to section 3 of the Act with respect to such wool product, subject, however, to the provisions of Rule 4

RULE 4—*Use of Registered Number in Lieu of Manufacturer's Name*

(*a*) The name of the manufacturer need not appear upon the label or mark of identification if the same bears an identification number registered and assigned by the Federal Trade Commission as the mark which identifies the manufacturer and by which said manufacturer undertakes to be bound in respect of such label as fully as though the name of the manufacturer were used in lieu of such number *Provided, however,* that such label or mark of identification bears, in addition to such number, the name of at least one person who subsequently sells such product to a reseller or to the purchaser-consumer, and the name of such seller, together with the manufacturer's registered number, remains or is set forth upon such label or mark affixed to the product when it is delivered to and received by the purchaser-consumer

(*b*) *Applications for Manufacturer's Registered Identification Number* Any manufacturer of a wool product residing in the United States desiring to use a manufacturer's registered number in lieu of his name upon the label or mark of identification affixed to the product by him, as provided for in this rule, may make application to the Federal Trade Commission for assignment to him of such registered number or numbers as, and in the form which, the Commission may deem appropriate for use by such manufacturer on the label or mark of identification under the Act in lieu of his name, but with fully as binding effect as though his name were used Such application shall be in writing, duly executed under oath or affirmation, and shall be submitted in quadruplicate and in the following form

"To the Federal Trade Commission,
Washington, D C

We, the undersigned, manufacturers of wool products subject to the Wool Products Labeling Act of 1939, residing in the United States and having principal office and place of business at ____,
(*Street and Number*) (*City or County*) (*State or Territory*)
do hereby make application to the Commission for the assignment of a manufacturer's registered identification number to be used by us on our labels and marks of identification in accordance with requirements of the

Commission and the applicable provisions of the rules and regulations under said Act.

It is understood by us and hereby agreed that, in the use of any such number assigned by the Federal Trade Commission, such number shall be construed as identifying us and as binding us as fully and in all respects as though our name were used on such labels and marks of identification in lieu of such manufacturer's number

Dated, signed and executed this ____ day of ____________ 19 ___, at ____________ ____________

(City or County) (State or Territory)

____

(Full Name of Firm)

____

(Signature and title of proprietor, partner or executive officer thereunto duly authorized)

Subscribed and sworn to (or affirmed) before me by

____

(Name of proprietor, partner or executive officer who signed as thereunto duly authorized)

this ____ day of ____________, 19____

____

Notary Public in and for
County of ____________,
State of ____________,

[*Notarial Seal*] *My commission expires*____________"

(*c*) If such applicant is a corporation, the application shall be duly executed in the name of such corporation and in accordance with the requirements of the following form:

"In witness whereof the ____________________________,

(Full Legal Name of Corporation)

the undersigned applicant herein, a corporation chartered and doing business under the laws of the State of ____________________,
having principal office and place of business
at ____________________________,

(Street and Number) (City or County) (State or Territory)

has this ____ day of ____________, 19____, caused this application to be executed and its name and corporate seal to be hereto affixed

____

(Full Legal Name of Corporation)

[*Corporate Seal*]

By____________________________

(Signature and Title of Executive Officer)

ATTEST

____

Secretary

On this ____ day of ____________, 19____, subscribed and sworn to (or affirmed) before me by ____________________,

(Name of Subscribing Executive Officer)

who on his oath (or affirmation) deposes and states that he is ____________________ of the above-named corporation,

(Title of Executive Officer)

that he is authorized to sign and has signed the foregoing application for and on behalf of such corporation

____

Notary Public in and for
County of ____________,
State of ____________,

[*Notarial Seal*] *My commission expires* ____________"

(*d*) The application shall be accompanied by statement of the business conducted by the applicant and designation of the kinds of wool products manufactured or sold by such applicant.

RULE 5—*Types of Labeling and Methods of Affixing Marks to Product*

The stamp, tag, label, or other means of identification shall be such as is appropriate to the nature of the product and shall be affixed to the product securely and with sufficient permanency to remain thereon in a conspicuous, clear, distinct and plainly legible condition throughout the sale, resale, distribution and handling incident thereto, and shall remain on or be firmly affixed to the respective product when sold and delivered to purchasers and purchaser-consumers thereof. Where these requirements are met, the stamp, tag, label, or other means of identification may be affixed by having the required information stencilled, imprinted or branded upon the product itself, or placed thereon in the form of a strong, durable label securely sewed or stapled to the product or otherwise securely attached thereto, or by a strong, durable tag securely tied to the product. (See Rule 15 for provision as to marking containers or packaging of wool products.)

RULE 6—*Labels to be Avoided*

Stamps, tags, labels, or other marks of identification which are insecurely attached, or which in the course of offering the product for sale, selling, reselling, transporting, marketing, or handling incident thereto are likely to become detached, indistinct, obliterated, illegible, mutilated, inaccessible, or inconspicuous, shall not be used.

RULE 7—*English Language Requirement*

All words, statements and other information required by or under authority of the Act and the rules and regulations thereunder to appear on the stamp, tag, label, or other mark of identification, shall appear in the English language. If the product bears any stamp, tag, label, or mark of identification which contains any of the required information in a language other than English, all of the required information shall appear both in such other language and in the English language.

RULE 8—*Common Generic Name of Fiber*

Except where another name is required or permitted under the Act, the respective common generic name of the fiber shall be used when naming fibers in the required information; as for example, "Wool," "Reprocessed Wool," "Reused Wool," "Cotton," "Rayon," "Silk," "Linen," "Horsehair," "Rabbit Hair."

RULE 9—*Abbreviations or Ditto Marks*

Words or terms in the required information descriptive of fiber content shall not be abbreviated, nor be designated by the use of ditto marks, but shall be spelled out fully; as for example, "Wool," "Reprocessed Wool," "Reused Wool," "Cotton," "Rayon."

RULE 10—*Arrangement of Label Information*

(*a*) All items or parts of the required information to be shown and displayed in the stamp, tag, label, or other mark of identification of the product shall be set forth consecutively, in immediate conjunction with each other, and in type or lettering plainly legible and conspicuous, such as for example:

"Made of
60% WOOL
40% REUSED WOOL
Exclusive of Ornamentation

Distributed by.
JOHN Q. DOE CO., INC,
New York, N Y."

(*b*) If non-required information or representations are placed on the product or in the label or mark of identification, the same shall not in any way be false or deceptive, nor shall such information or representation be set forth or used in such manner as to interfere with the required information

RULE 11—*Improper Methods of Labeling*

The stamp, tag, label, or other mark of identification required under the Act, or the required information contained therein, shall not be minimized, rendered obscure or inconspicuous, or be so placed as likely to be unnoticed or unseen by purchasers and purchaser-consumers when the product is offered or displayed for sale or sold to purchasers or the consuming public, by reason of, among others.

(*a*) Small or indistinct type

(*b*) Failure to use letters and numerals of equal size and conspicuousness in naming all fibers and percentages of such fibers as required by the Act

(*c*) Insufficient background contrast

(*d*) Crowding, intermingling, or obscuring with designs, vignettes, or other written, printed, or graphic matter.

RULE 12—*Marking of Units of Merchandise Containing Two or More Pieces*

(*a*) Except in instances where other form of marking is specifically authorized, the stamp, tag, label, or other mark of identification, shall be attached to and appear upon each garment or separate piece of merchandise subject to the Act, irrespective of whether two or more garments or pieces may be introduced into commerce, sold, or marketed together or in combination with each other

(*b*) *Wearing Apparel Sold in Pairs—Hosiery, Gloves, Mittens, Footwear, etc* In the case of garments or wearing apparel manufactured for use in pairs and sold, distributed and used in such pairs, the use of more than one label or mark of identification will not be required if both pieces in the pair are of the same fiber composition, grade and quality, are and remain firmly attached to each other when marketed and delivered in the channels of trade and to the purchaser-consumer, and the stamp, tag, label, or mark of identification affixed thereto is clearly applicable to both pieces and supplies the required information prominently in accordance with the Act and the rules and regulations thereunder.

RULE 13—*Real Name to be Shown on Label*

Trade names, trade-marks or other names which do not constitute the legal name of the manufacturer of the wool product or other person required by the Act to appear on the stamp, tag, label, or other mark of identification, shall not be used in lieu of or in substitution for the legal name of such manufacturer or other person Nothing in these rules shall be construed as permitting the use of any corporate, trade, or other name which is false or deceptive

RULE 14—*Substitute Label Requirement*

When necessary to avoid deception, the name of any person other than the manufacturer of the product appearing on the stamp, tag, label, or other mark of identification affixed to such product shall be accompanied by appropriate words showing that the product was not manufactured by such person; as for example

"Manufactured for ______________________"
"Distributed by ______________________"
"______________________ Distributors"

RULE 15—*Labeling of Containers or Packaging of Wool Products*

The label or mark of required information, as provided in Rule 5, shall be affixed to and displayed upon the container, wrapper, binder, or other means of packaging of wool products subject to the Act,

(*a*) where marking the product itself is impossible, or where such marking of the product would be inadequate to fully inform purchasers and purchaser-consumers of the required information or to prevent deception, or

(*b*) where the wool product is marketed or sold and delivered in sealed containers which remain unbroken and intact until after delivery of the product to, and receipt thereof by, the purchaser-consumer. Any such product packaged in a sealed container shall also be marked by stamp, tag, label, or other mark of identification showing the required fiber and material content where the product is capable of being so marked and where it is removed from the sealed container, or is likely to be removed therefrom, or the container is opened, for display or sales purposes or for other reasons, prior to purchase by and delivery to the ultimate purchaser-consumer Where the product bears a label or mark of identification, as provided in Rule 5, which is clearly visible to the purchaser when offered for sale, no label or mark of identification need be placed on such container

RULE 16—*Ornamentation*

Where the wool product contains fiber ornamentation not exceeding 5% of the total fiber weight of the product and the stated percentages of fiber content of the product are exclusive of such ornamentation, the stamp, tag, label, or other means of identification shall contain a phrase or statement showing such fact; as for example·

"50% Wool
25% Reused Wool
25% Cotton
Exclusive of Ornamentation"

Where the fiber ornamentation exceeds 5%, it shall be included in the statement of required percentages of fiber content of the product, subject, however, to the right of making sectional disclosure of content under Rule 23 where the ornamentation constitutes a distinct section of the product and the provisions of such Rule 23 are fully met.

RULE 17—*Use of the Term "All" or "100%"*

Where the fabric or product to which the stamp, tag, label, or mark of identification applies is composed wholly of one kind of fiber, either the word "all" or the term "100%" may be used with the correct fiber name, as for example, "100% Wool," "All Wool," "100% Reprocessed Wool," "All Reprocessed Wool," "100% Reused Wool," "All Reused Wool" If any such product is composed wholly of one fiber with the exception of fiber ornamentation not exceeding 5%, such term "all" or "100%" as qualifying the name of the fiber may be used, provided it is immediately followed by the phrase "exclusive of ornamentation," or by a phrase of like meaning, such as for example.

"All Wool
Exclusive of Ornamentation"
or
"100% Wool
Exclusive of Ornamentation."

RULE 18—*Use of Name of Specialty Fiber*

In setting forth the required fiber content of a product containing any of the specialty fibers named in section 2(*b*) of the Act, the name of the specialty fiber present may be used in lieu of the word "wool," *provided* the percentage of each named specialty fiber is given, *and provided further* that the name of the specialty fiber so used is qualified by the word "reprocessed" or "reused" when the fiber referred to is "reprocessed wool" or "reused wool," as defined in the Act. The following are examples of fiber content designation permitted under this rule:

reclaimed, reworked, reprocessed or reused from any spun, woven, knitted, felted, or manufactured or used product Products composed of or made from fiber reworked or reclaimed from yarn or clips shall not be described as virgin wool or new wool, or by terms of similar import, regardless of whether such yarn or clips are new or used or were made of new or reprocessed or reused material.

RULE 21—*Use of Separate Label for Name*

The name of the manufacturer or person subject to section 3 of the Act with respect to the wool product may be set forth on a label or mark separate from that which contains the statement of fiber and material content of the product where it is not practical to include such name in the label or mark bearing the fiber and material content, *provided* that the label or mark bearing said name and the name itself are prominently and conspicuously displayed either in immediate conjunction with, or in close proximity to, such other label or mark and in such manner as will fully inform purchasers and purchaser-consumers of the required information This rule shall not apply to a manufacturer's registered number provided for in Rule 4

RULE 22—*Marking of Samples, Swatches or Specimens.*

Where samples, swatches or specimens of wool products subject to the Act are used to promote or effect sales of such wool products in commerce, said samples, swatches and specimens, as well as the products themselves, shall be labeled or marked to show their respective fiber contents and other information required by law.

RULE 23—*Sectional Disclosure of Content*

(a) *Permissive.* Where the wool product is composed of two or more sections which are recognizably distinct and such several sections are of different fiber composition, the required fiber content to be stated upon the stamp, tag, label, or other mark of identification may be separated in the same label or mark in such manner as to show the fiber composition of each section, provided the section to which the respective percentages and fiber designations apply is specifically designated and such disclosure by sections is adequate fully to inform purchasers of the required information

(b) *Mandatory.* The disclosure by sections as above provided shall be made in all instances where such form of marking is necessary to avoid deception of purchasers and purchaser-consumers.

RULE 24—*Linings, Paddings, Stiffening, Trimmings and Facings*

(a) In labeling or marking garments or articles of apparel which are wool products, the fiber content of any linings, paddings, stiffening, trimmings or facings of such garments or articles of apparel shall be given and shall be set forth separately and distinctly in the stamp, tag, label, or other mark of identification of the products,

(1) if such linings, paddings, stiffening, trimmings or facings purport to contain or are represented as containing wool, reprocessed wool or reused wool; or

(2) if express or implied representations of fiber content of any of such linings, paddings, stiffening, trimmings or facings are customarily made.

(b) In the case of wool products which are not garments or articles of apparel, but which contain linings, paddings, stiffening, trimmings or facings, the stamp, tag, label, or other mark of identification of the product shall show the fiber content of such linings, paddings, stiffening, trimmings or facings, set forth separately and distinctly in the stamp, tag, label, or other mark of identification,

(*c*) In the case of garments which contain interlinings, the fiber content of such interlinings shall be set forth separately and distinctly as part of the required information on the stamp, tag, label, or other mark of identification of such garment For purposes of this paragraph (*c*) the term "interlinings" shall not be construed as embracing paddings or stiffening ordinarily used in garments for structural purposes and not for warmth

(*d*) Wool products which are or have been manufactured for sale or sold for use as linings, interlinings, paddings, stiffening, trimmings or facings, but not contained in a garment, article of apparel, or other product, shall be labeled or marked with the required information as in the case of other wool products

RULE 25—*Naming Fibers Not Present*

Words which constitute the name or designation of a fiber which is not present in the product shall not appear in or as a part of the listing or marking of required fiber content on the stamp, tag, label, or other mark of identification affixed to the wool product.

RULE 26—*Pile Fabrics and Products Composed Thereof*

The fiber content of pile fabrics or products made thereof may be stated in the label or mark of identification in such segregated form as will show the fiber content of the face or pile and of the back or base, with the percentages of the respective fibers as they exist in the face or pile and in the back or base, *provided* that in such disclosure the respective percentages of the face and the back be given in such manner as will show the ratio between the face and the back Examples of the form of marking pile fabrics as to fiber content provided for in this rule are as follows

"100% Wool Pile
100% Cotton Back
(Back constitutes 60% of fabric
and pile 40%)"

"Pile—60% Reused Wool, 40% Wool
Back—70% Cotton, 30% Rayon
(Pile constitutes 60% of fabric
and back 40%)"

RULE 27—*Wool Products Containing Superimposed or Added Non-Woolen Fiber*

Where the product is made wholly of wool, reprocessed wool, or reused wool, with the exception of a non-woolen fiber in minor proportion which is superimposed or added in certain distinct areas or sections for reinforcing or for other useful purpose, the product may be designated as all wool, all reprocessed wool, or all reused wool, as the case may be, with an exception naming the non-woolen fiber and giving the percentage thereof and indicating the area or section where superimposed or added for reinforcement or other useful purpose. An illustration of the type of statement provided for in this rule to designate the fiber content of hosiery composed entirely of reused wool, but having 15% cotton added to the toe and heel for reinforcement, is as follows

"All reused wool except 15% cotton reinforcement added to toe and heel"

RULE 28—*Products Made Wholly of Miscellaneous Reused Fibers of Undetermined Percentages*

Where a wool product is made of shoddy or material composed wholly of reused miscellaneous fibers of which the respective percentages of the differ-

ent fibers and the variations thereof are not determined, the following form of disclosure as to fiber content of such wool product, where truthfully applicable, may be used for such classes of merchandise, with the proper percentage figures inserted

"Made of Reused material
consisting of:
Not less than ——% reused wool
Not more than ——% cotton
Balance ——% unknown reused fibers"

or

"Made of Reused material
consisting of:
Not less than ——% reused wool
Not more than ——% rayon
Balance ——% unknown reused fibers"

For purposes of this rule undetermined or unascertained amounts of wool or reprocessed wool may be classified and designated as reused wool.

RULE 29—*Garments or Products Composed of or Containing Miscellaneous Cloth Scraps*

(*a*) For wool products which consist of, or are made from, miscellaneous cloth scraps comprising manufacturing by-products and containing various fibers of undetermined percentages, the following form of disclosure as to fiber content of such wool products, where truthfully applicable and with appropriate percentage figure inserted, may be used in the stamp, tag, label, or mark of identification of such product.

(1) Where the product contains chiefly cotton as well as woolen fibers in the minimum percentage designated for reused wool

"Made of
Miscellaneous Cloth Scraps
Composed Chiefly of Cotton with
Minimum of ——% Reused Wool"

---

(2) Where the product contains chiefly rayon as well as woolen fibers in the minimum percentage designated for reused wool

"Made of
Miscellaneous Cloth Scraps
Composed Chiefly of Rayon with
Minimum of ——% Reused Wool"

---

(3) Where the product is composed chiefly of a mixture of cotton and rayon as well as woolen fibers in the minimum percentage designated for reused wool:

"Made of
Miscellaneous Cloth Scraps
Composed Chiefly of Cotton and Rayon
with Minimum of ——% Reused Wool"

---

(4) Where the product contains chiefly woolen fibers with the balance of undetermined mixtures of cotton, rayon or other non-woolen fibers

"Made of
Miscellaneous Cloth Scraps
Containing Cotton, Rayon and Other
Non-woolen fibers, with
Minimum of ——% Reused Wool."

(*b*) Where the cotton or rayon content or the non-woolen fiber content mentioned in such forms of disclosure is not known to comprise as much as 50% of the fiber content of the product, the words "Chiefly of" in the respective form of disclosure specified in this rule shall be omitted

(*c*) The words "Contents are" may be used in the above-mentioned forms of marking in lieu of the words "Made of" where appropriate to the nature of the product.

(*d*) For purposes of this rule, undetermined or unascertained amounts of wool or reprocessed wool which may be contained in the product may be classified and designated as reused wool

RULE 30—*Deceptive Labeling in General*

Products subject to the Act shall not bear, nor have used in connection therewith, any stamp, tag, label, mark or representation which is false, misleading or deceptive in any respect.

MANUFACTURERS' RECORDS

RULE 31—*Maintenance of Records*

In pursuance of the provisions of section 6 of the Act, every manufacturer of a wool product subject to the Act, irrespective of whether any guaranty has been given or received, shall maintain proper records showing the fiber content, as required by the Act, of all such wool products made by such manufacturer The records so maintained shall show:

(*a*) The percentage of wool, reprocessed wool, and reused wool, and of each kind of fiber other than wool, placed in the respective wool products of such manufacturer in the form of fiber, yarn, fabric, or other form; and

(*b*) Such numbers, information, marks or means of identification as will identify the said records with the respective wool products to which they relate.

Manufacturers shall also keep and maintain as records under the Act all invoices, purchase contracts, orders or duplicate copies thereof, bills of purchase, business correspondence received, factory records, and other pertinent documents and data showing or tending to show (1) the purchase, receipt, or use by such manufacturer of all fiber, yarn, fabric or fibrous material, or any part thereof, introduced in or made a part of any such wool products of said manufacturer, (2) the content, composition or classification of such fiber, yarn, fabric or fibrous material with respect to the information required to appear upon the label of the wool products of such manufacturer, and (3) the name and address of the person or persons from whom such fiber, yarn, fabric or fibrous materials were purchased or obtained by such manufacturer

GUARANTIES

RULE 32—*Form of Separate Guaranty.*

The following is a suggested form of separate guaranty under section 9 of the Act which may be used, by a guarantor residing in the United States or place subject to its jurisdiction, on and as part of an invoice, bill of sale or other sales document in which the merchandise covered is listed and

specified and shows the date of such document and date of shipment of the merchandise

"We, the undersigned, manufacturers of the above-specified merchandise which is subject to the Wool Products Labeling Act of 1939, hereby guarantee that each such article therein is stamped, tagged, labeled or marked with the fiber content and other information as required by said Act, and that none of such articles or products is misbranded within the meaning of said Act

JOHN DOE COMPANY, INC.,
New York, N. Y.
By________________________
President"

RULE 33—*Continuing Guaranty*

A continuing guaranty under section 9 of the Act, when properly executed and fully conforming to the requirements of the Act and the rules and regulations thereunder, may be filed with the Federal Trade Commission If a continuing guaranty is filed with the Commission, it shall be filed in triplicate, each fully executed, and shall be renewed annually thereafter and at such other times as any change is made in ownership or management of the guarantor Such guaranty shall be set forth on 8½" x 11" sheets of white bond paper of good quality and shall be printed, lithographed, or typed in clearly legible form, with margins of at least 1" width on all sides, and with all signatures thereon written in ink. In the event the principal place of business of the guarantor is removed to another address, such change of address shall be reported promptly to the Commission by the guarantor If the guarantor is a corporation, the guaranty shall be executed in the name of the corporation by an executive officer thereof thereunto duly authorized by the corporation, and shall be attested by the Secretary and the corporate seal affixed thereto. If the business of the guarantor is owned and operated by an individual, it shall be signed and executed by such individual; if owned and operated as a partnership or as an unincorporated association of individuals, it shall be signed and executed on behalf of the partnership or association and the members thereof by one or more of the partners or, in the case of such association, by one or more of the individuals and members actively engaged in the business The guaranty shall be acknowledged before a Notary Public in accordance with the prescribed form * The following are prescribed as forms of continuing guaranty

(FORM A—FOR USE BY CORPORATIONS)

CONTINUING GUARANTY

UNDER THE

WOOL PRODUCTS LABELING ACT OF 1939

The undersigned, ____, a corporation residing in the United States, chartered and existing under the laws of the State of ____________________ and engaged in the business of manufacturing or selling wool products which are subject to the Wool Products Labeling Act of 1939, with principal office and place of business at ____,
(*Street and Number*) (*City or County*) (*State or Territory*)

* Blank forms of continuing guaranties as needed may be procured from the Commission upon request

DOES HEREBY GUARANTEE that every such wool product contained in each shipment or other delivery hereafter made by it pursuant to purchases made by customers will be, when so shipped and delivered, properly stamped, tagged, labeled or marked, showing the fiber content and other information required by said Act and the rules and regulations thereunder, and that no article or product in any such shipment or delivery will be misbranded within the meaning of the said Act

Dated, signed and executed this ________ day of ____________, 19____, at ______________________________

(City or County) (State or Territory)

____
(Name of Corporation)

____
(Executive Officer authorized to sign)

[CORPORATE SEAL]

____
(Title of Executive Officer)

ATTEST

____
Secretary

State of ______________________ }
} ss
County of _____________________ }

On this ________ day of ______________, 19____, before me personally appeared ______________________________,
(Name of Executive Officer signing)

______________________ of ______________________,
(Title of Executive Officer) (Name of Corporation)

to me personally known, and acknowledged the execution of the foregoing instrument on behalf of said corporation for the uses and purposes therein stated

____
Notary Public

[NOTARIAL SEAL]

My commission expires____________

(FORM B—FOR USE BY INDIVIDUALS)

CONTINUING GUARANTY

UNDER THE

WOOL PRODUCTS LABELING ACT OF 1939

The undersigned, ______________________________, residing in the United States and doing business under the name of ______________________________, with principal offices and place of business at ______________________________,

(Street and Number) (City or County) (State or Territory)

and engaged in the business of manufacturing or selling wool products which are subject to the Wool Products Labeling Act of 1939, DOES HEREBY GUARANTEE that every such wool product contained in each shipment or other delivery hereafter made by him pursuant to purchases made by customers will be, when so shipped and delivered, properly stamped, tagged, labeled or marked showing the fiber content and other information required

by said Act and the rules and regulations thereunder, and that no article or product in any such shipment or delivery will be misbranded within the meaning of said Act

Dated, signed and executed this ____________ day of ____________,
19____, at ____
(City or County) (State or Territory)

____
(Signature of Proprietor)

____
(Name under which business is conducted)

State of ________________________ }
} ss
County of ______________________ }

On this ____________ day of ________________, 19_____, before me personally appeared the said ________________________________,
(Name of proprietor signing)

to me known to be the person described in and who executed the foregoing instrument, and acknowledged the execution of the same for the uses and purposes therein stated

____
Notary Public

[NOTARIAL SEAL]

My commission expires______________

(FORM C—FOR BUSINESS CONDUCTED BY PARTNERSHIP OR UNINCORPORATED ASSOCIATION)

CONTINUING GUARANTY

UNDER THE

WOOL PRODUCTS LABELING ACT OF 1939

This is to certify that the undersigned, ________________________________,
(Name of subscribing member)

together with ____
(Full names of all partners, or if association names of members
________________________________, all residing in the United States
owning and operating business)

and doing business under the name and style
of ____,
(Insert trade name under which business is conducted)

with principal office and place of business
at ____,
(Street and Number) (City or County) (State or Territory)

and engaged in the business of manufacturing or selling wool products which are subject to the Wool Products Labeling Act of 1939, DO HEREBY GUARANTEE that every such wool product contained in each shipment or other delivery hereafter made by them pursuant to purchases made by customers will be, when so shipped and delivered, properly stamped, tagged, labeled or marked showing the fiber content and other information required by said Act and the rules and regulations thereunder, and that no article or product in any such shipment or delivery will be misbranded within the meaning of said Act

IN WITNESS WHEREOF, the said ________________________________
(Name of person executing the guaranty)

being thereunto duly authorized has hereunto subscribed his name and executed this instrument for and on behalf of said ________________________ and the members thereof

(*Partnership or Association*)

this ______ day of______ ____________, 19____, in ________________________

(*City or County*)

____

(*State or Territory*)

____

(*Signature of subscribing member*)

____

(*Name of partnership or association*)

State of ____________ ____________ }
} *ss*
County of ____________ ____________ }

On this ______ day of ____________, 19 ____, before me personally appeared ________________________, to me known to be the person

(*Name of subscribing member*)

described in and who executed the foregoing instrument, and acknowledged the execution of the same in the capacity and for the uses and purposes therein stated

____

Notary Public

[NOTARIAL SEAL]

My commission expires____________

RULE 34—*Reference to Existing Guaranty on Labels Not Permitted*

No representation or suggestion that a wool product is guaranteed under the Act by the Government, or any branch thereof, shall be made on or in the stamp, tag, label, or other mark of identification applied or affixed to wool products

GENERAL

RULE 35—*Hearings Under Section 4 (d) of the Act*

Hearings under section 4 (*d*) of the Act will be held when deemed by the Commission to be in the public interest Interested persons may file applications for such hearings Such applications shall be filed in quadruplicate and shall contain a detailed technical description of the class or classes of articles or products regarding which applicant requests a determination and announcement by the Commission concerning express or implied representations of fiber content of articles or concerning insignificant or inconsequential textile content of products

Promulgated and made effective by the Federal Trade Commission July 15, 1941

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